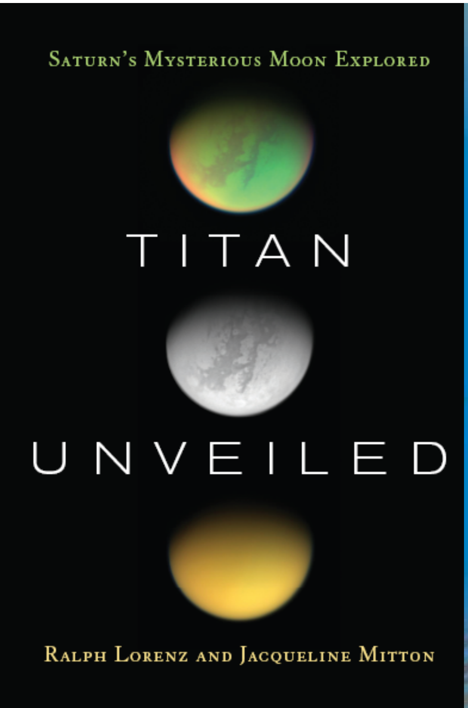
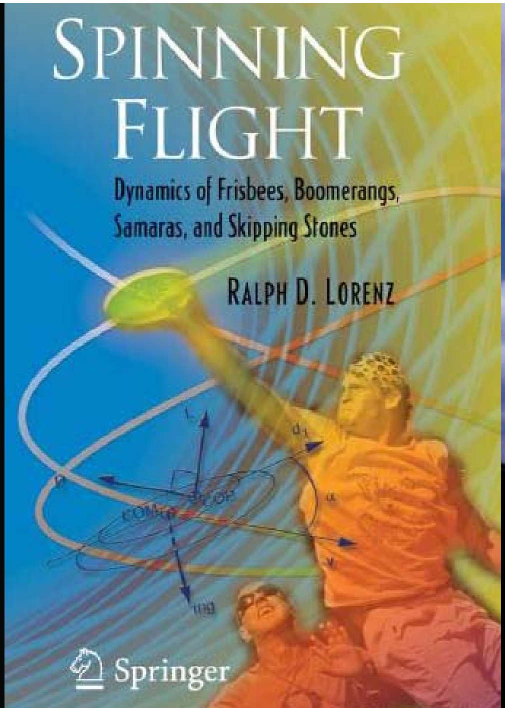
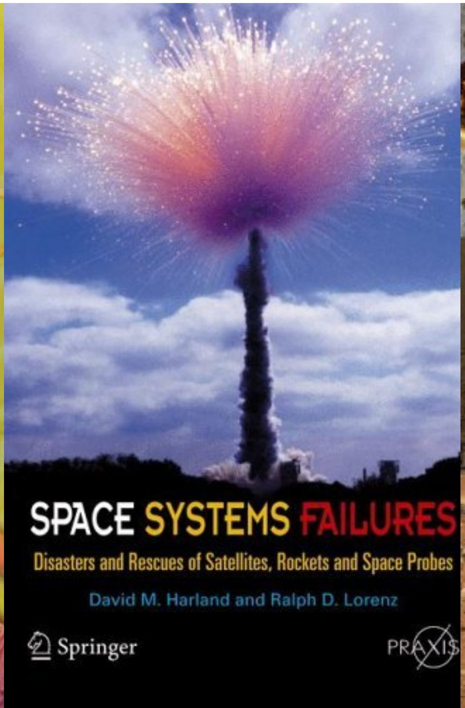
Acoustics Measurements on the Huygens Probe and other Platforms - A Review

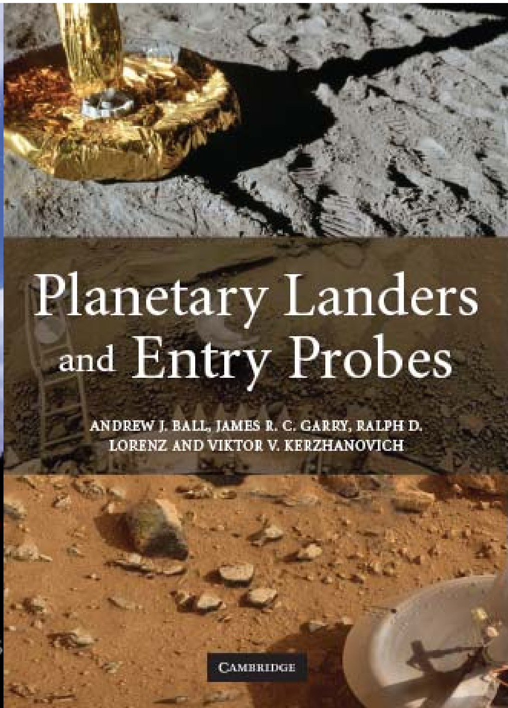
Ralph Lorenz

JHU-APL









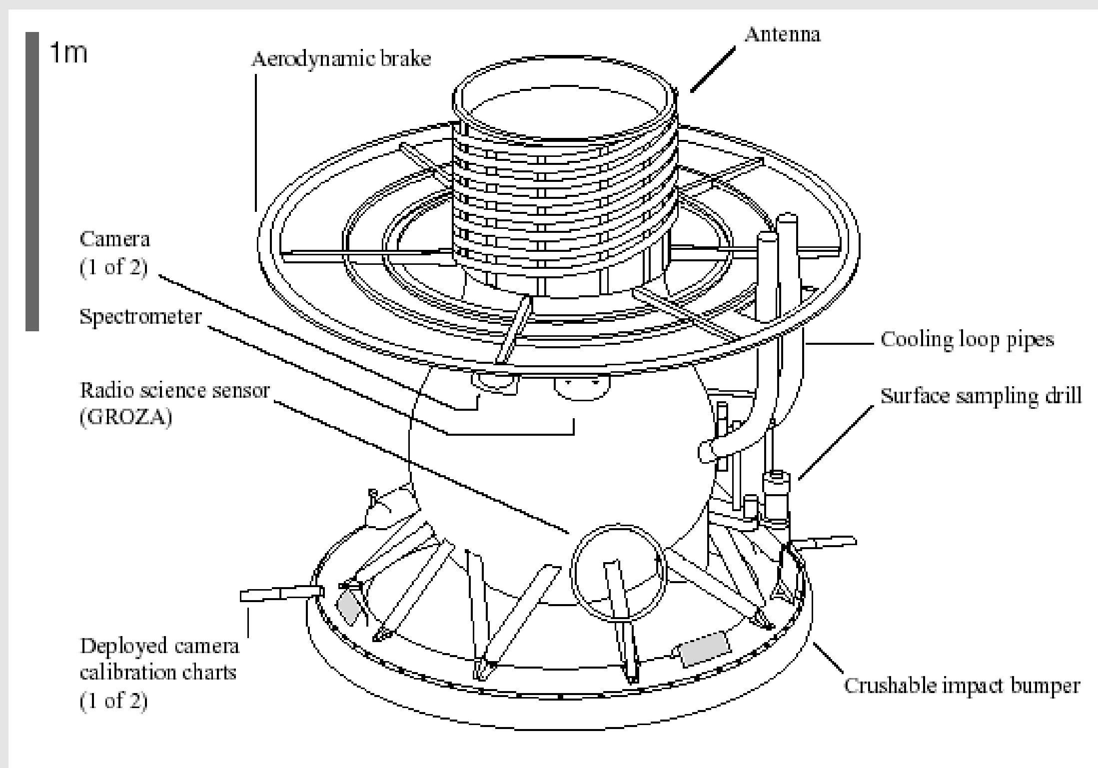


Figure 18.9 Venera 11, 12.

Figure from Ball et al., Planetary Landers and Entry Probes, CUP, 2007

'Groza' instrument on Venera 11,12. (Groza-2 on V13/14) Passive acoustic sensing to detect thunder.

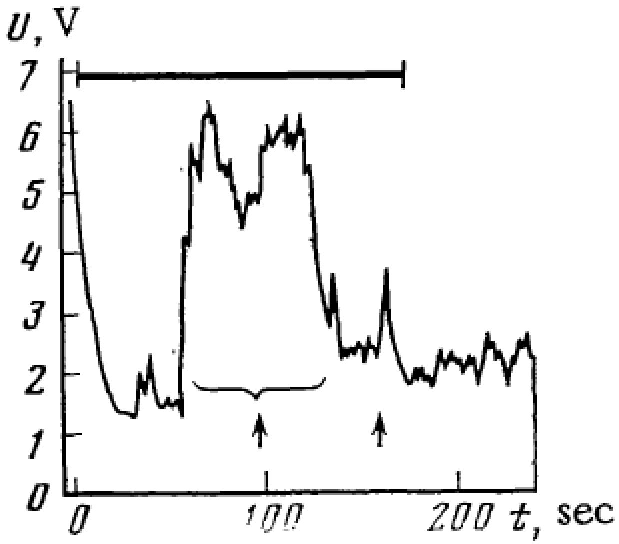
The Groza 2 experiment aboard the landing craft comprised a microphone and appropriate electronic circuitry for measuring acoustic noise both along the descent path and on the surface of the planet. The electromagnet-type microphone remained operational at temperatures up to 800 K and pressures up to 100 bar. The microphone accommodated a 2-kHz frequency band, from 400 to 2500 Hz, with peak sensitivity near 1700 Hz (under standard conditions).

Descent signals attributed to aeroacoustic noise.

Acoustic measurements of the wind velocity at the *Venera 13* and *Venera 14* landing sites

L. V. Ksanfomaliti, N. V. Goroshkova, M. K. Naraeva, A. P. Suvorov, V. K. Khondyrev, and L. V. Yabrova

Institute for Space Research, USSR Academy of Sciences, Moscow
(Submitted May 17, 1982)
Pis'ma Astron. Zh. 8, 419–423 (July 1982)



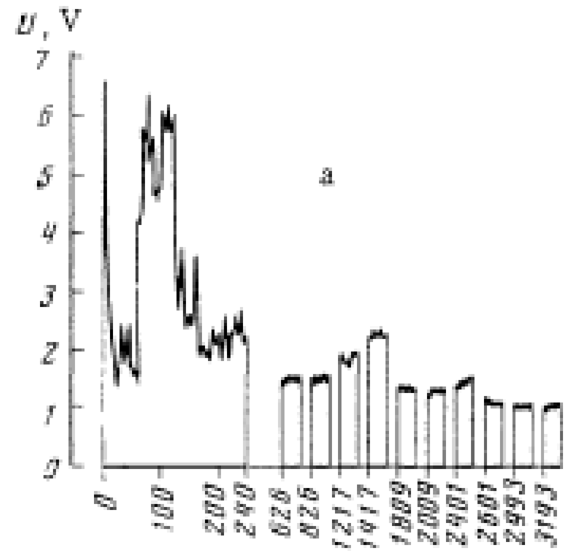
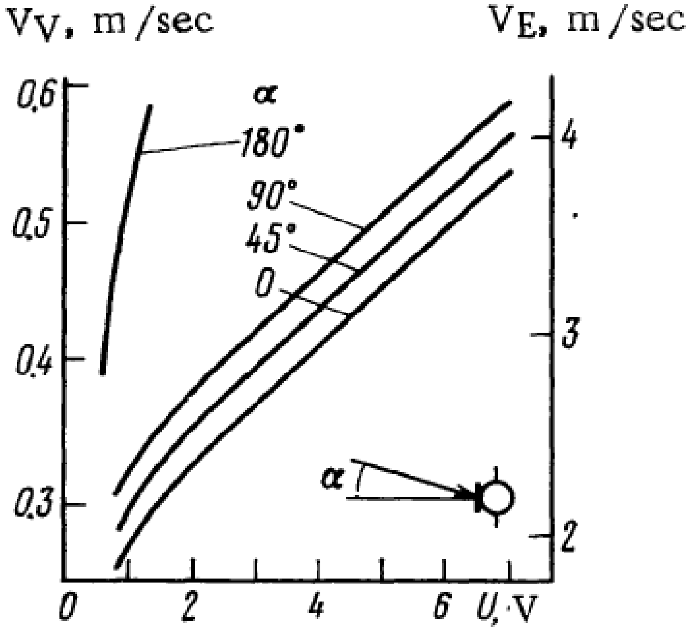


FIG. 1. Acoustic noise recorded by the Venera 14 lander on the surface of Venus, March 5, 1982. Vertical axis, output signal U (the full scale corresponds to the range from 55 to 82 dB; horizontal axis, elapsed time after landing. The heavy bar indicates the period when the spacecraft systems were operating. The arrows indicate noise associated with equipment operation. Presumably the signal from t = 180 to 240 sec represents wind noise in the microphone armature.

By interpreting the acoustic noise on the Venus surface as wind noise in the microphone armature, estimated wind velocities of 0.35-0.57 m/sec are obtained, in agreement with earlier measurements on other spacecraft. It is noted that these values are also consistent with the observed drift of fine soil particles across the surface of the spacecraft landing ring.



Dynamic Pressure scaling ρV^2

FIG. 2. Output signal U as a function of the wind velocity V_V on Venus and V_E on the earth when the microphone is employed as an anemometer. The angle α specifies the direction of the wind relative to the microphone diaphragm.

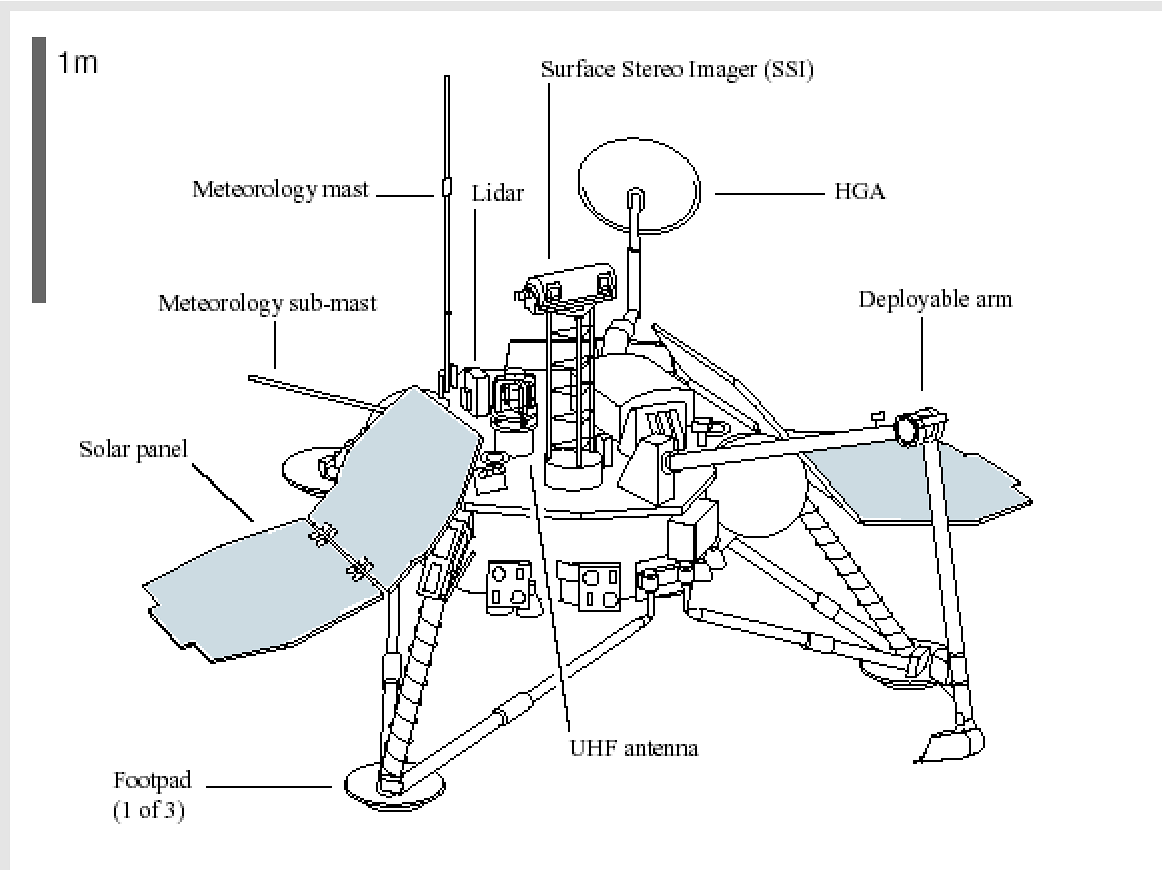
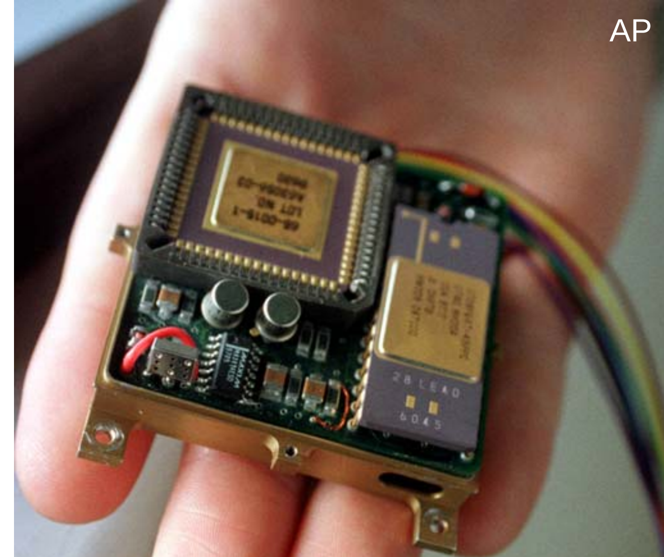
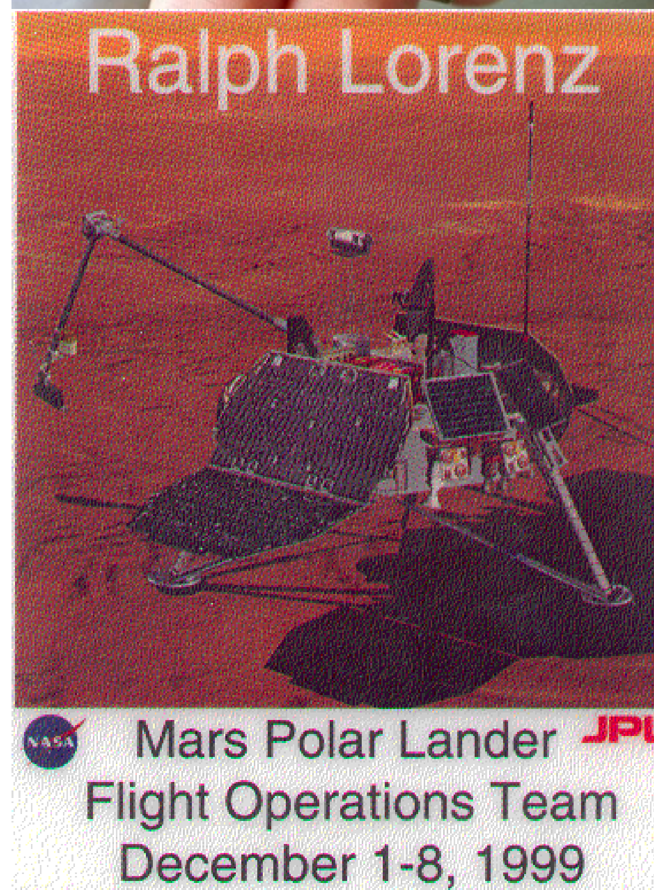


Figure 18.13 Mars Polar Lander.

Figure from Ball et al., Planetary Landers and
Entry Probes, CUP, 2007





UC Berkeley/The Planetary Society
Mars Microphone on Mars Polar Lander
(piggybacked on LIDAR) 0.050kg (<$100K?)
Variant developed for Netlander

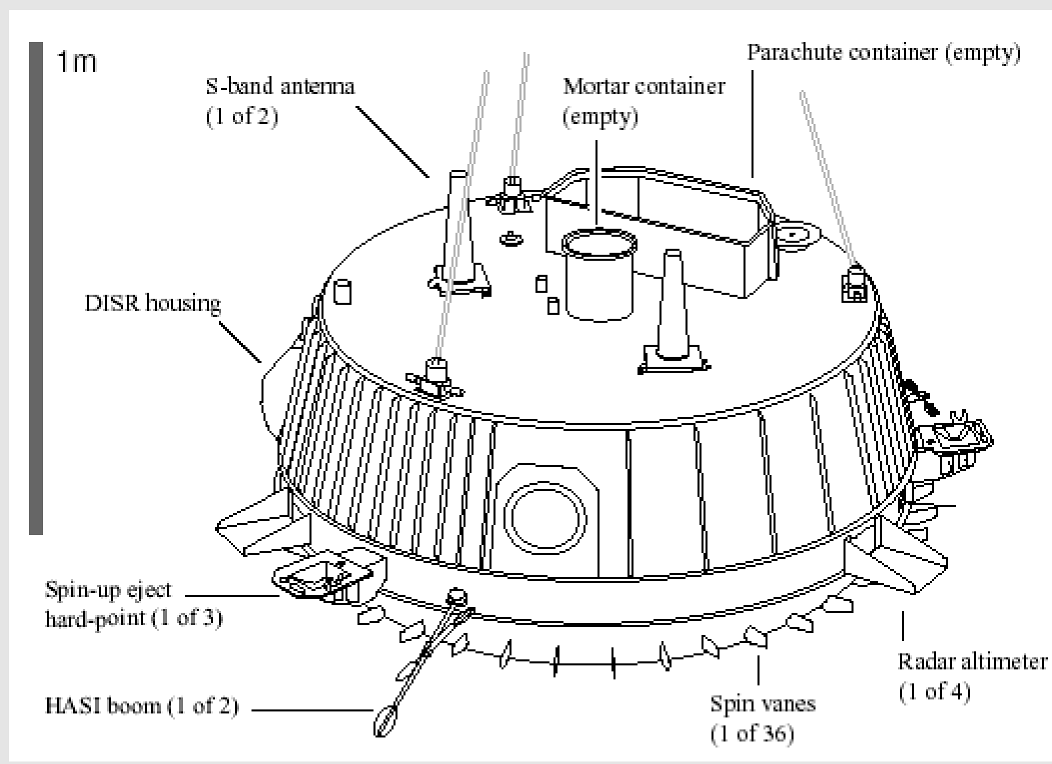
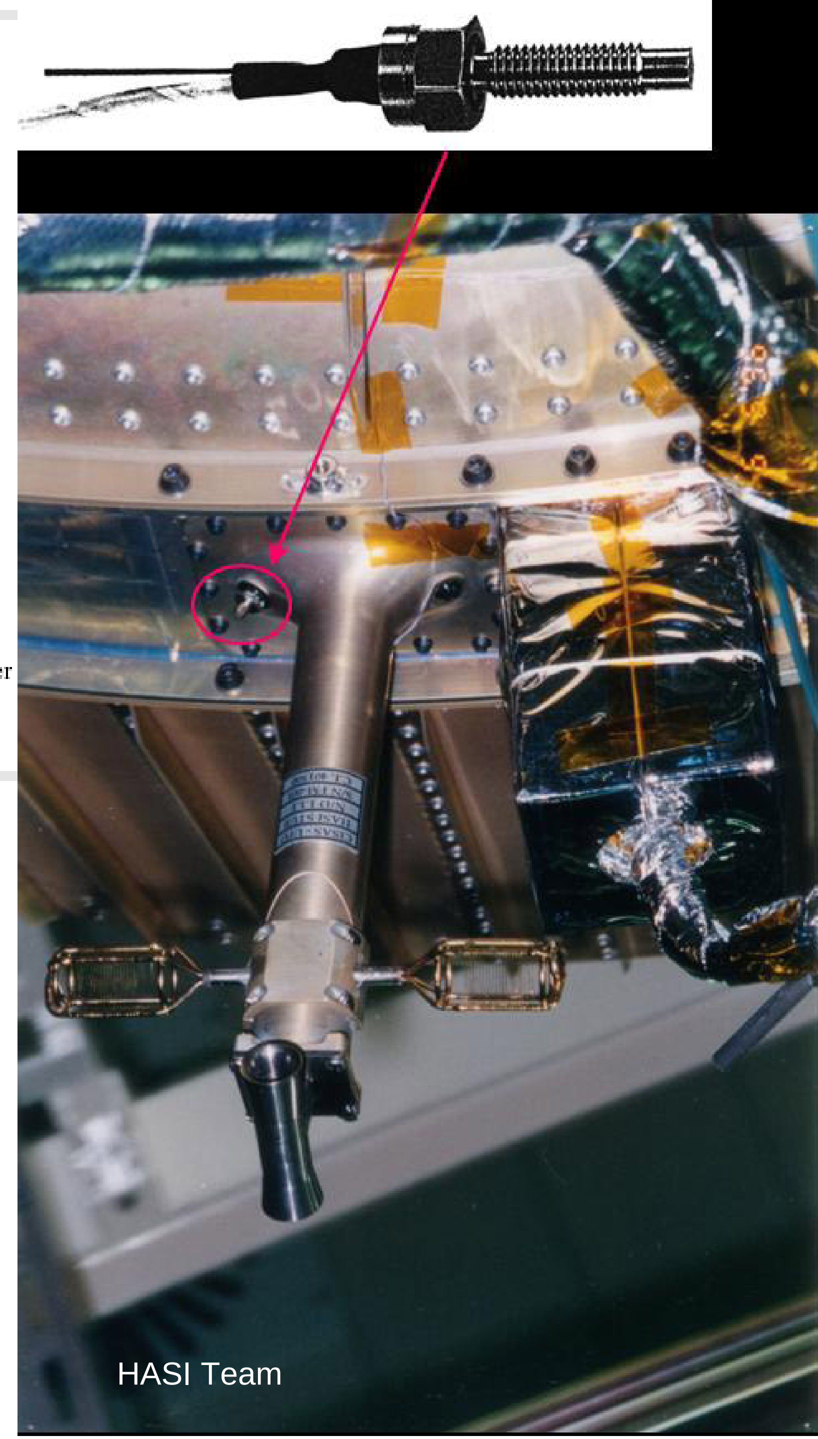


Figure 16.10 Huygens.

Figure from Ball et al., Planetary Landers and Entry Probes, CUP, 2007



Microphone processed by DSP in HASI Permittivity/Wave Analyzer

Overage 480 bps (cf 128 kbps MP3…)

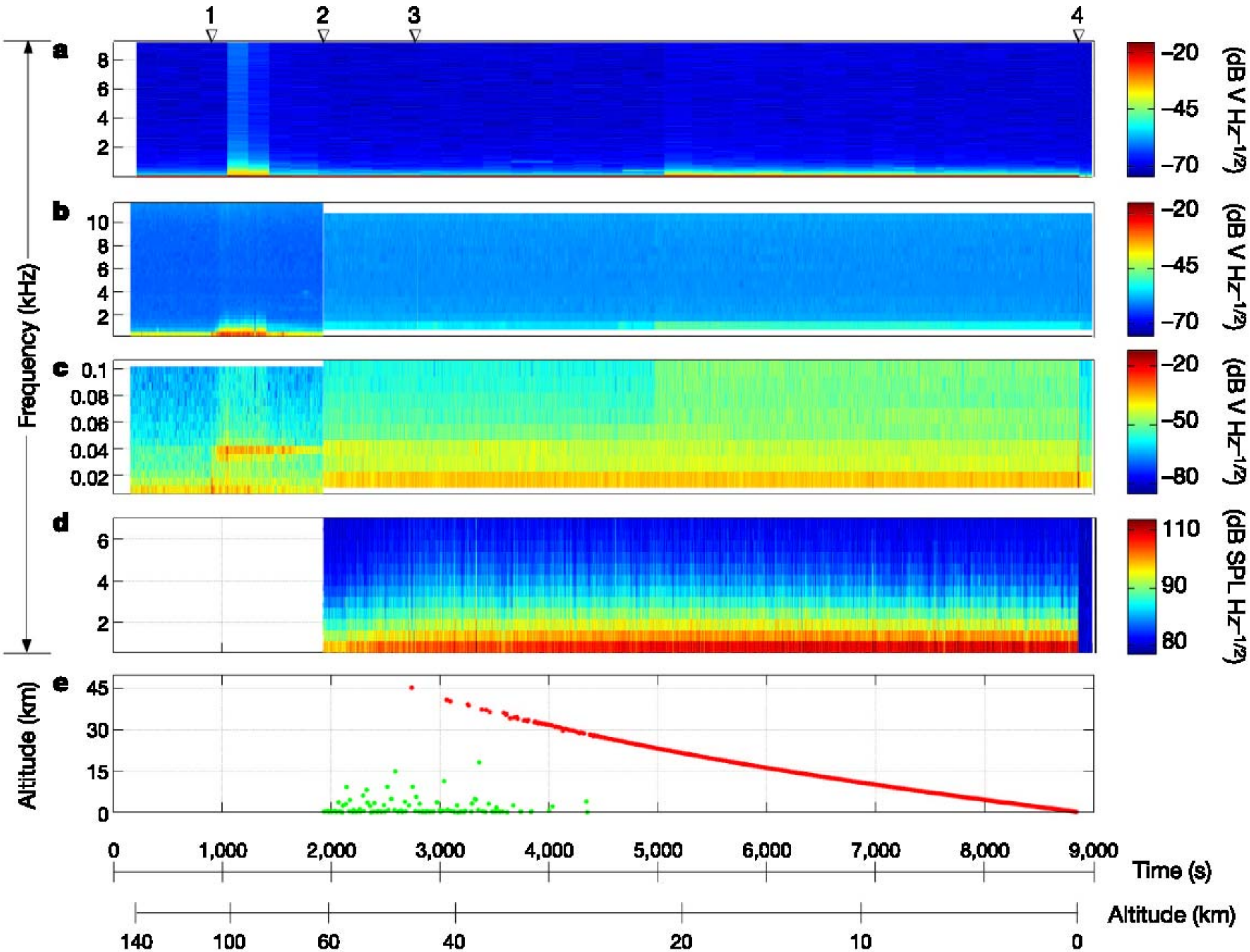
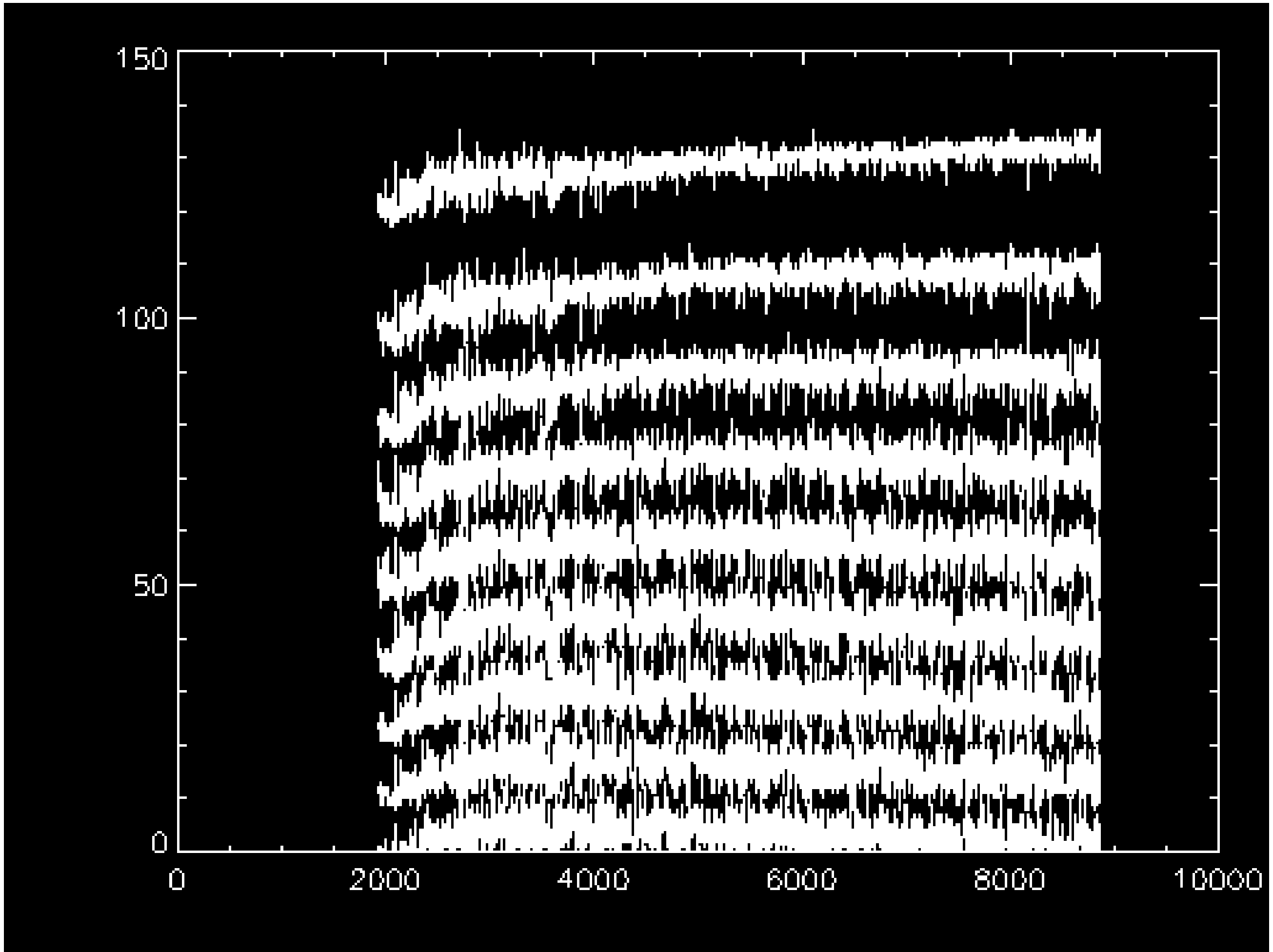


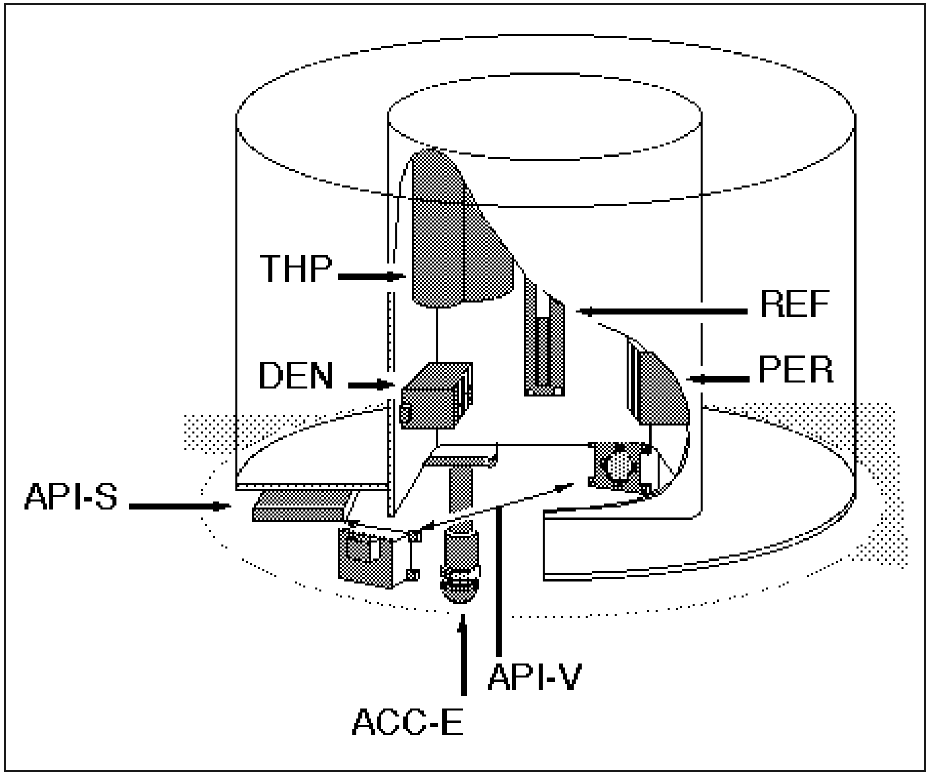
Figure from Fulchignoni et al., Nature, 2005

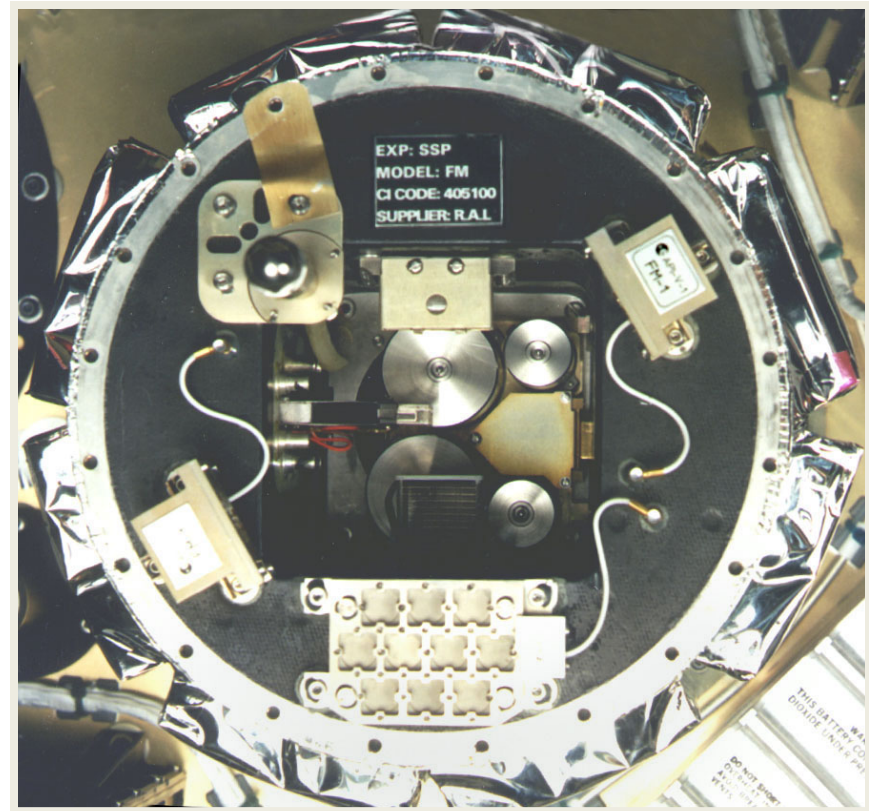
Signal more or less constant during descent. Why ?

Sound level corresponds to fluctuations in pressure sensed at microphone - forced by dynamic pressure during descent. Under a given parachute in steady descent dynamic pressure is simply weight per unit area - roughly constant (g, Re, M etc….)
Possible acoustic impedance effect at beginning ?



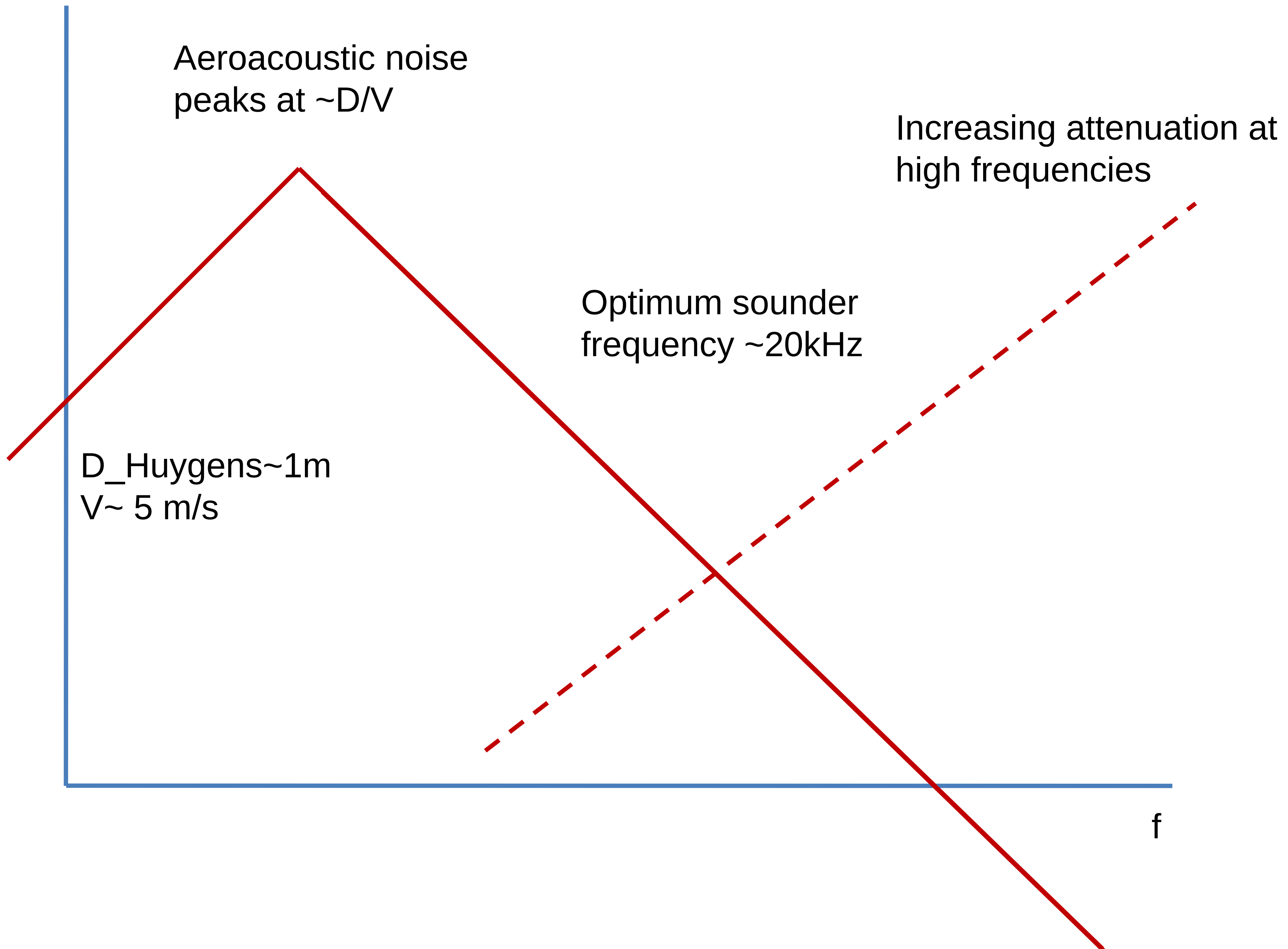
SSP ‘TopHat’ Layout



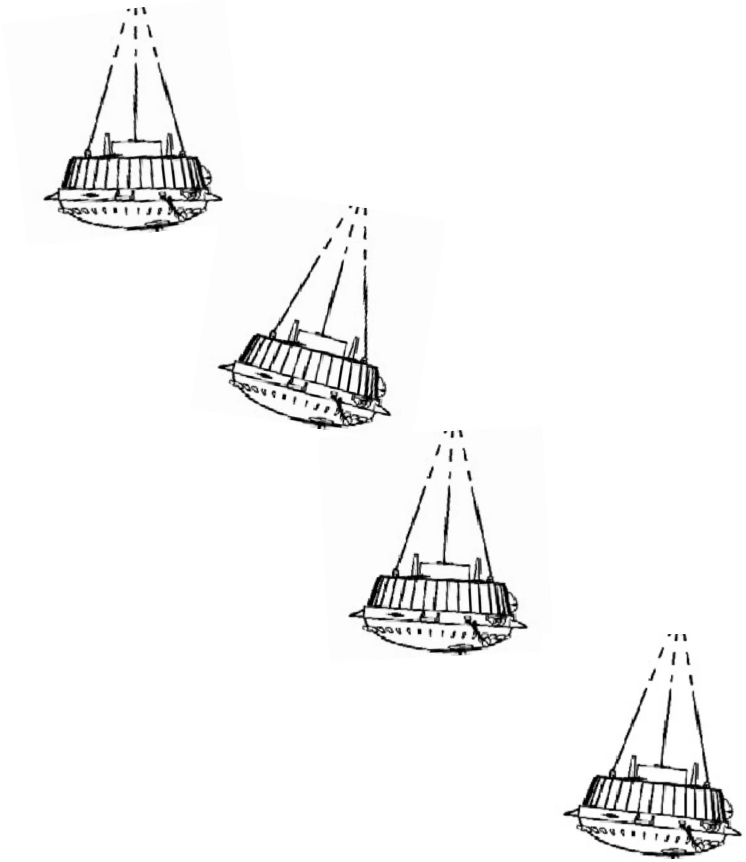


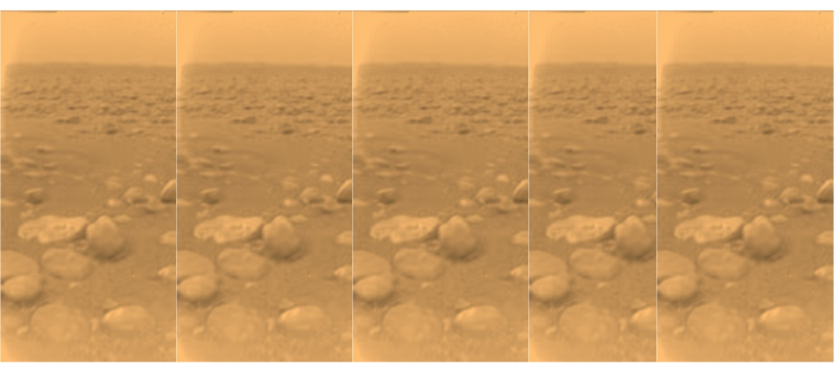
API-V: speed of sound in media
API-S: downward-looking sonar
THP: thermal properties of media
PER: electrical permittivity / conductivityREF: refractive index of liquid

DEN: density of liquid
ACC-E: landing impact force sensor
(ACC-I: acceleration on impact
TIL: angle of probe) - on electronics box



Aeroacoustic noise
peaks at ~D/V
Increasing attenuation at
high frequencies
Optimum sounder
frequency ~20kHz
D_Huygens~1m
V~ 5 m/s
f





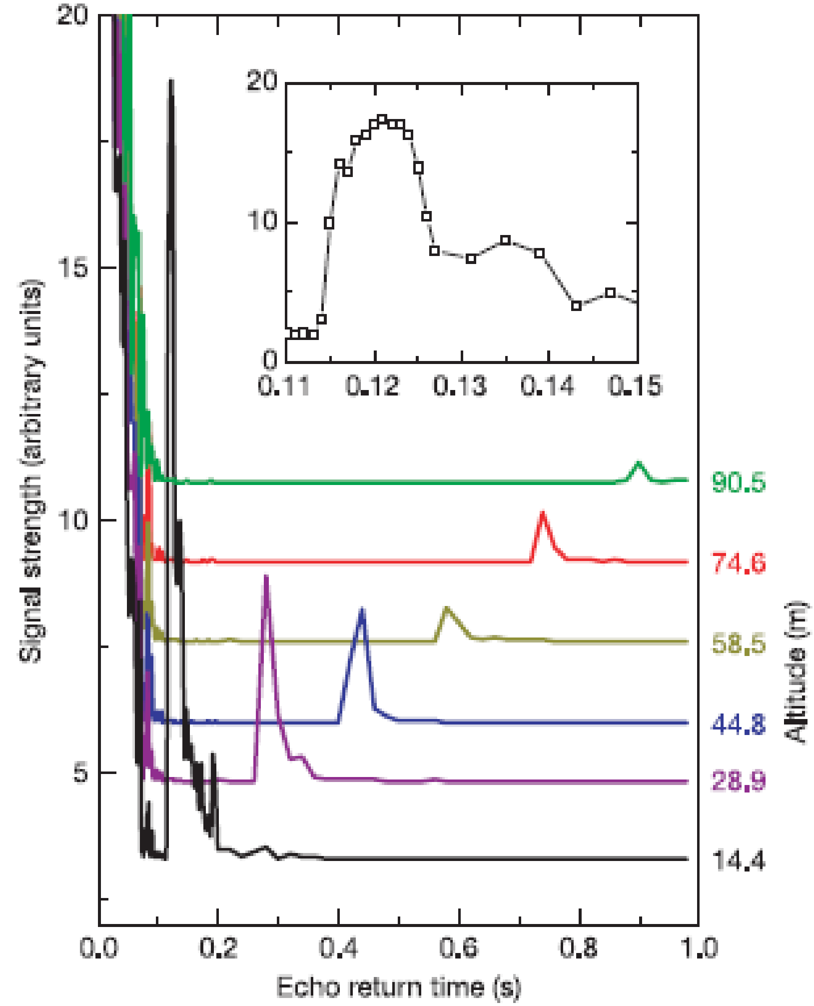
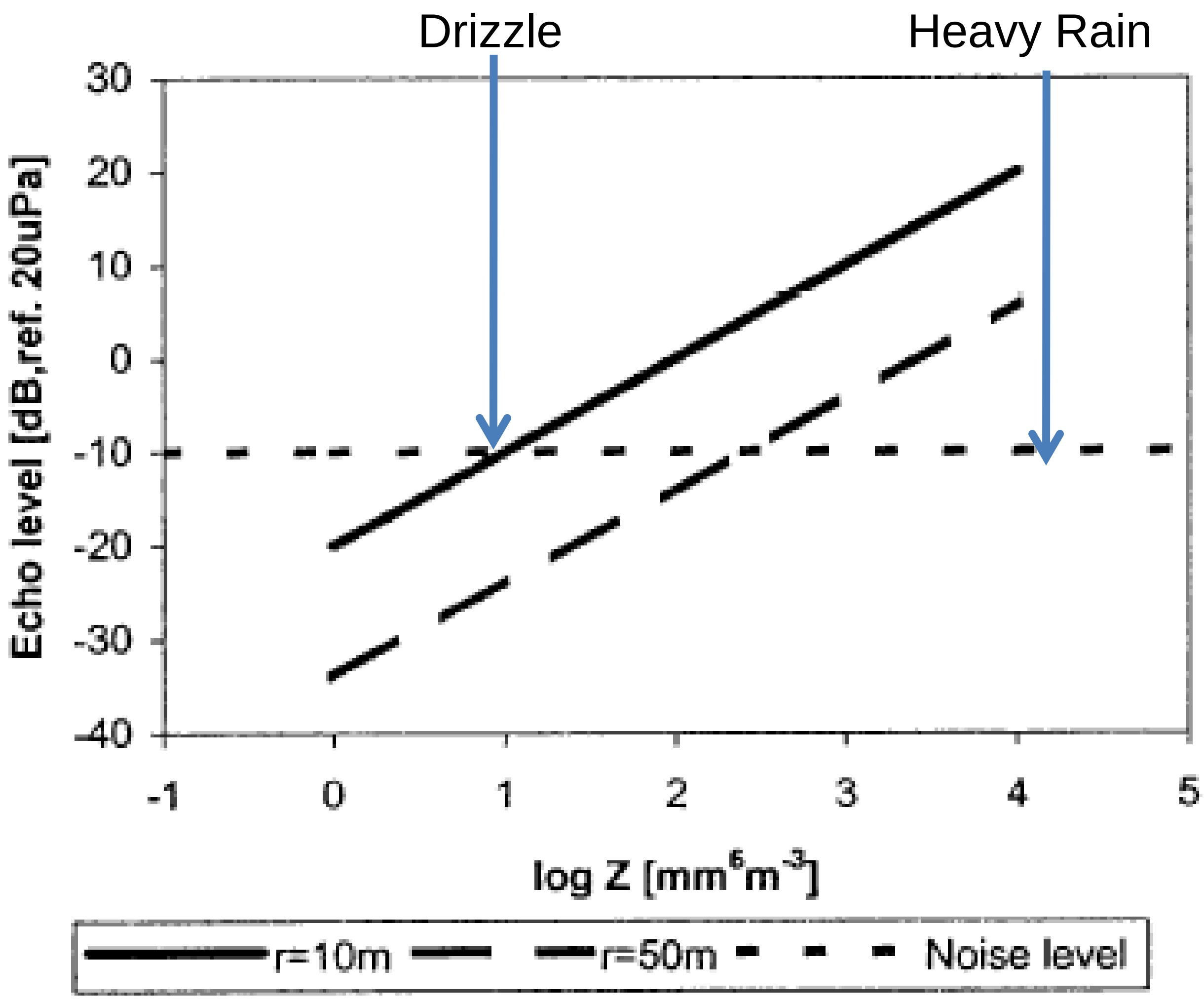


Figure 1 | Acoustic sonar (API-S) surface echoes. Note that the larger signals to the left of the plot are the result of the sensor ringing from the send pulse intruding into the receive time window. The inset is a zoom on the final API-S surface detection from 14.4 m altitude (at the time of pulse transmission). A speed of sound measurement of $191.9 \pm 1.8\ \mathrm{m\ s^{-1}}$ from the SSP Acoustic Velocity (API-V) sensors near the surface is used to convert ranging time delay into altitude.

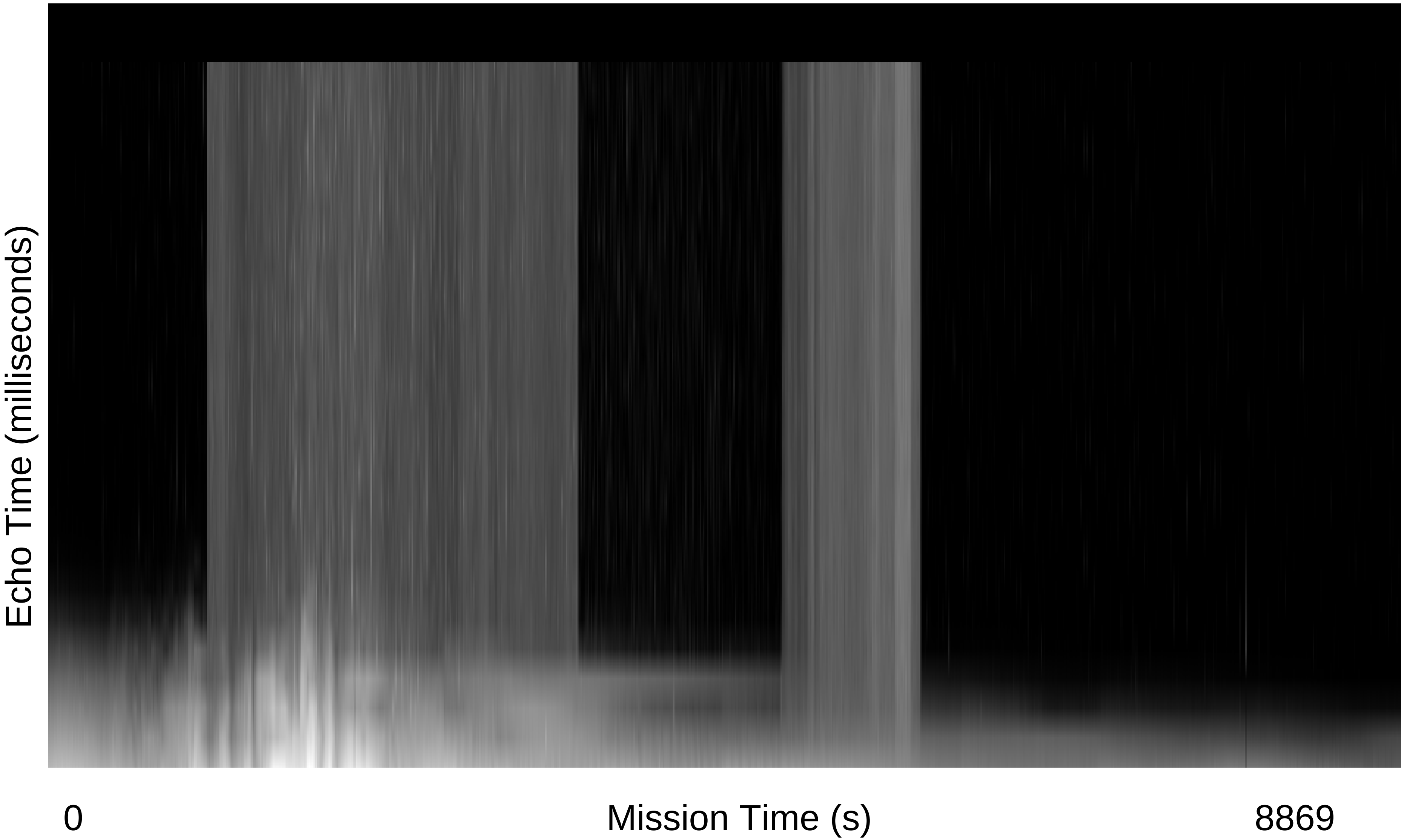
Zarnecki et al., Nature, 2005

SSP API-S as Weather 'Radar'

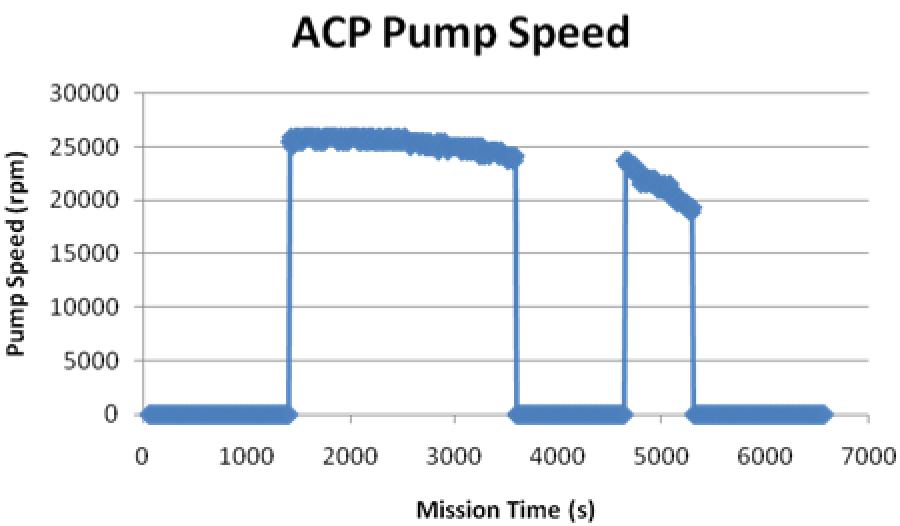


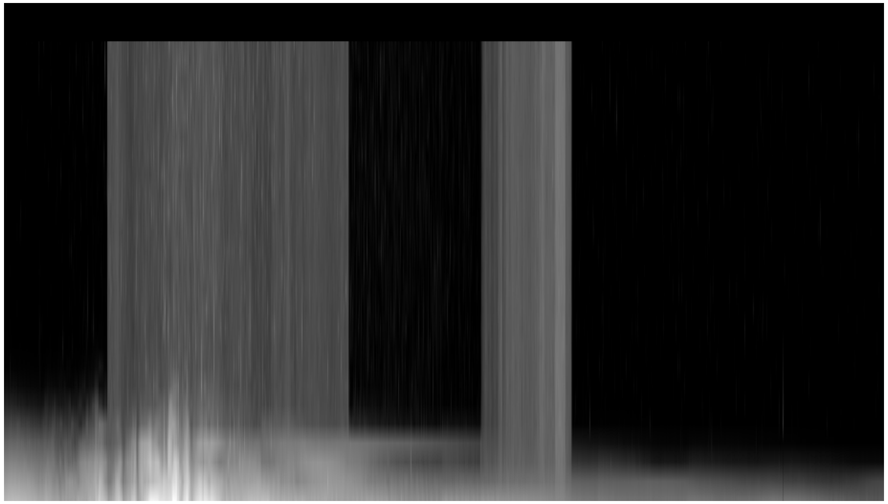
From Svedhem et al., Planetary Probe Atmospheric Entry and Descent Trajectory Analysis and Science, Lisbon, PT 2002 (aka IPPW-1) Proceedings ESA SP-544

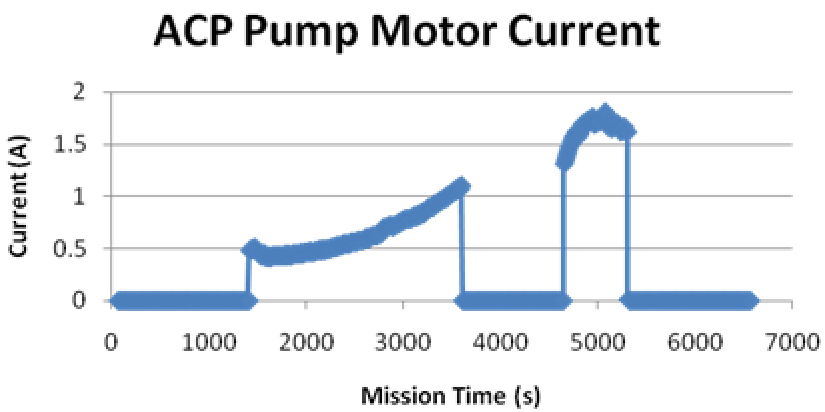
Search for atmospheric backscatter (turbulence, precipitation). 'Jammed' by external noise during two major episodes of descent

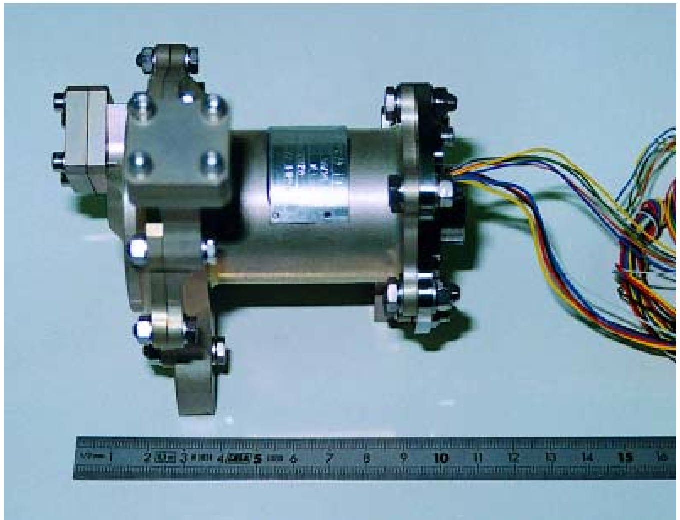


Descent mode observations dominated by noise from ACP pump



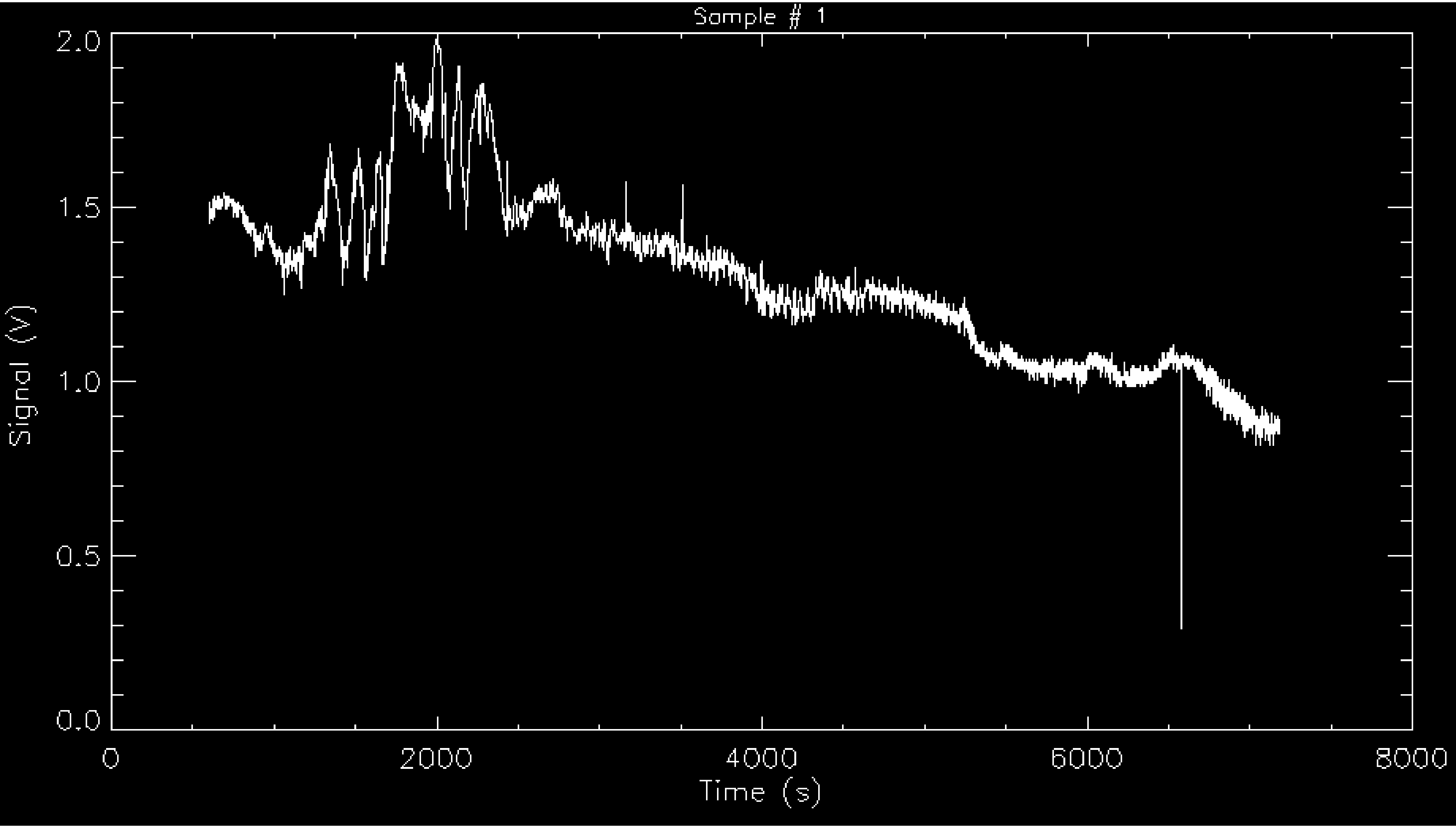




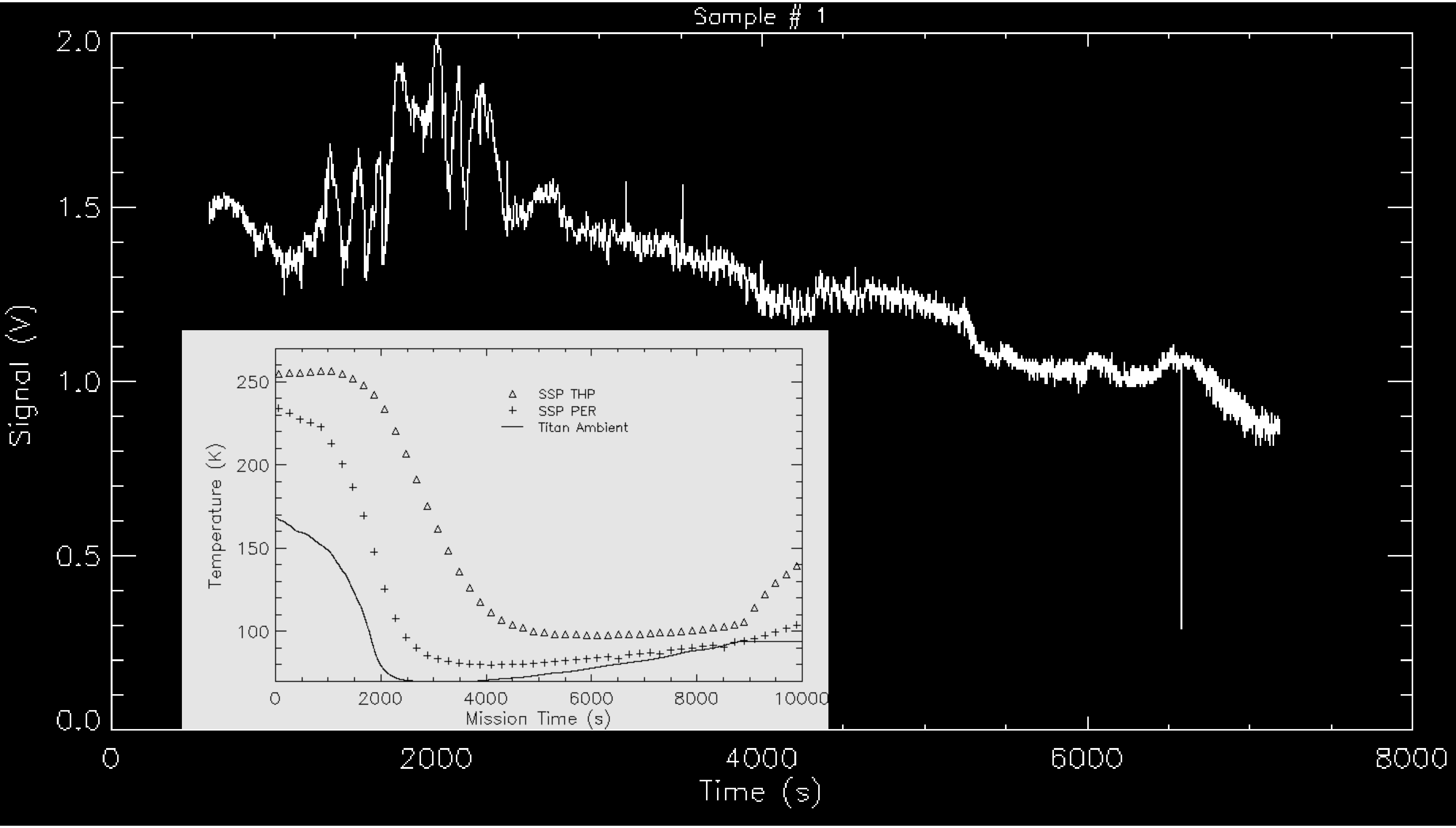


Tx ringing was noted to increase after launch: transducer elements shifted ?

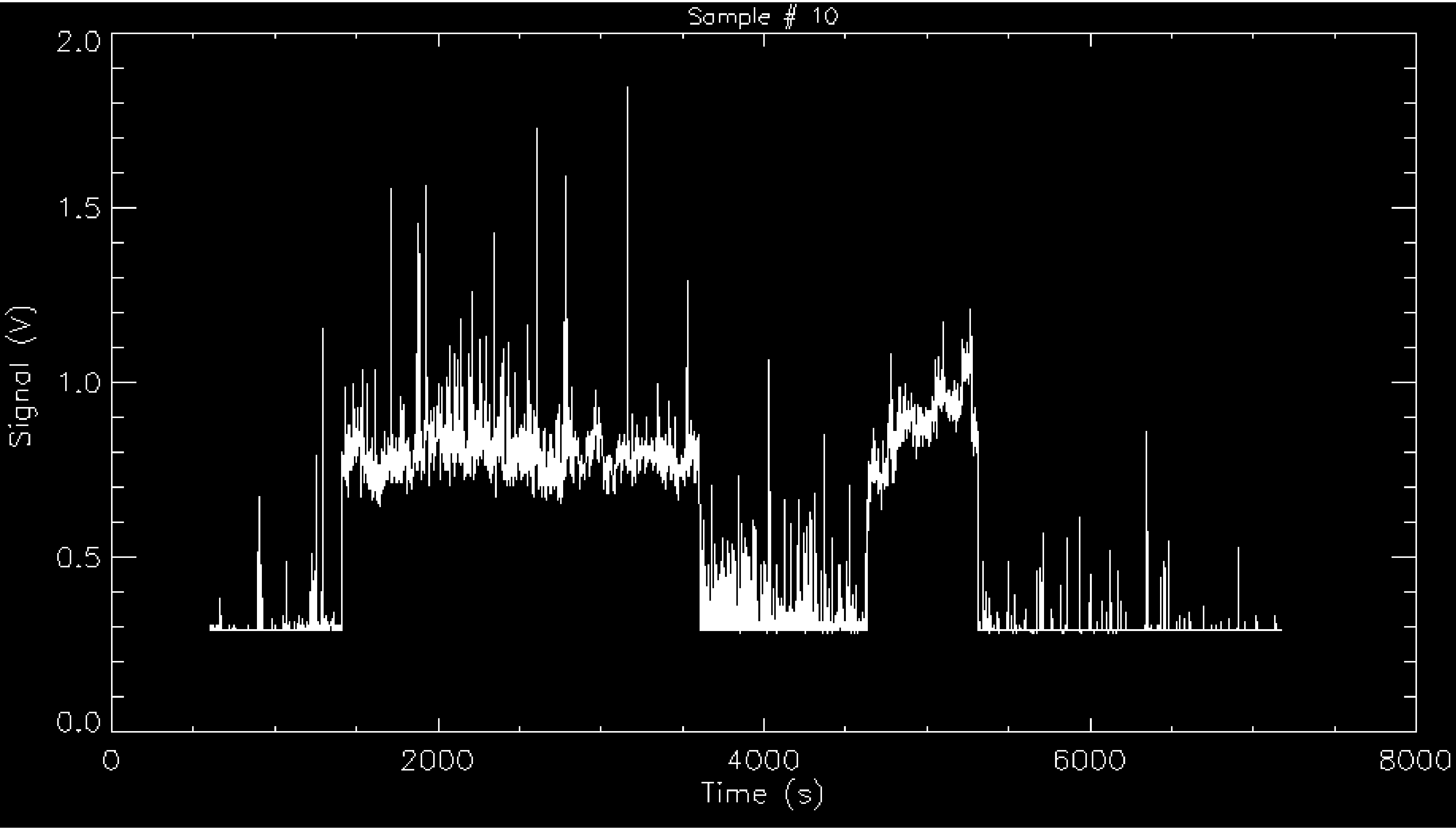
Signal in first bin (ringing) declines with time - better coupling of energy into denser atmosphere?

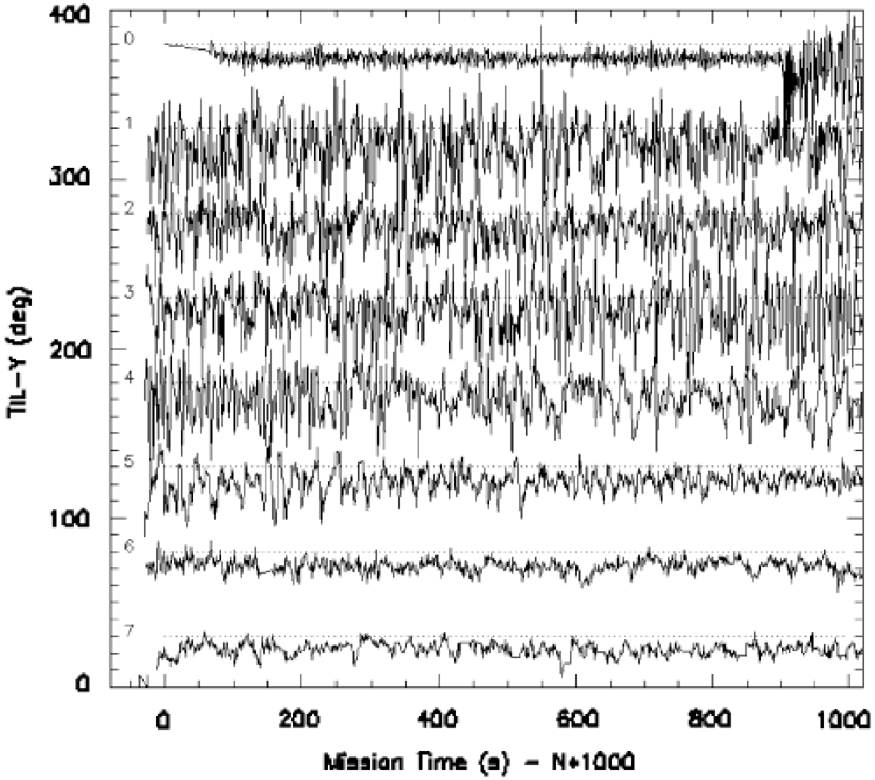


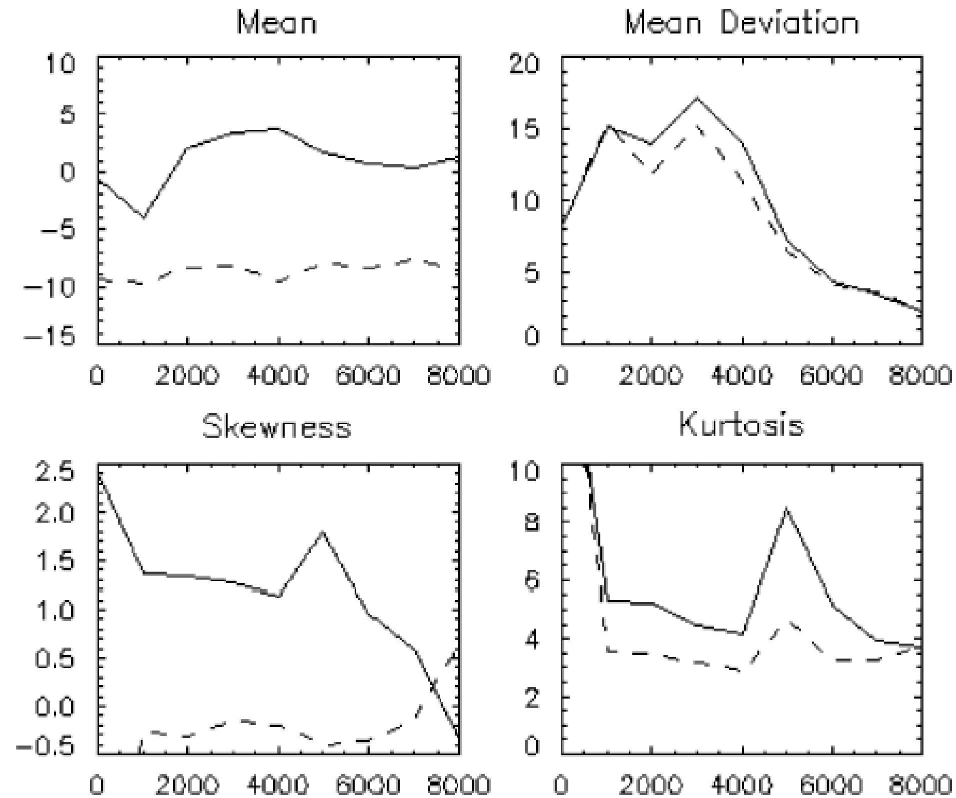
Odd character 1000-2500s….. Period of most rapid external temperature change… (although other things going on too..)



'base level' of signal in last bin dominated by ACP noise, but non-monotonic trend in the thee 'quiet' regions - 3700-4500s region has much more echo power than early and late phases







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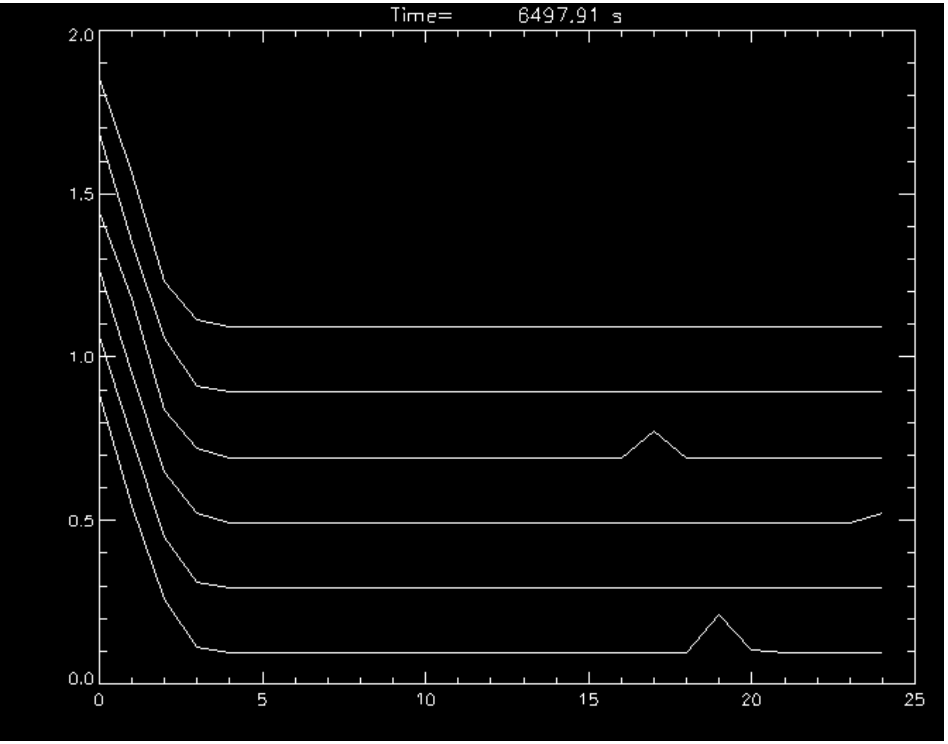
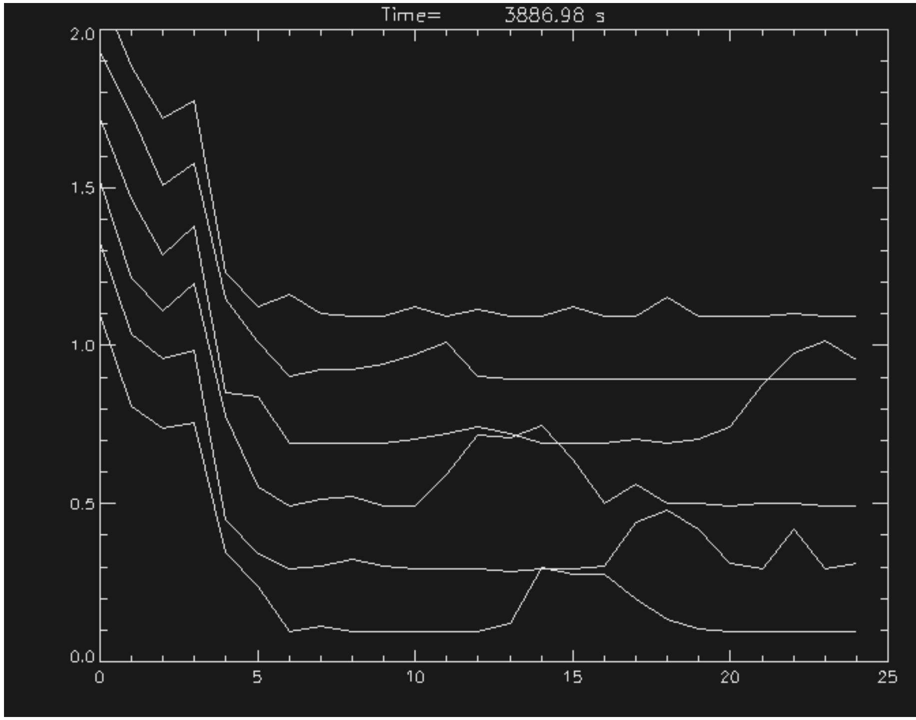
Descent motions of the Huygens probe as measured by the Surface Science Package (SSP): Turbulent evidence for a cloud layer

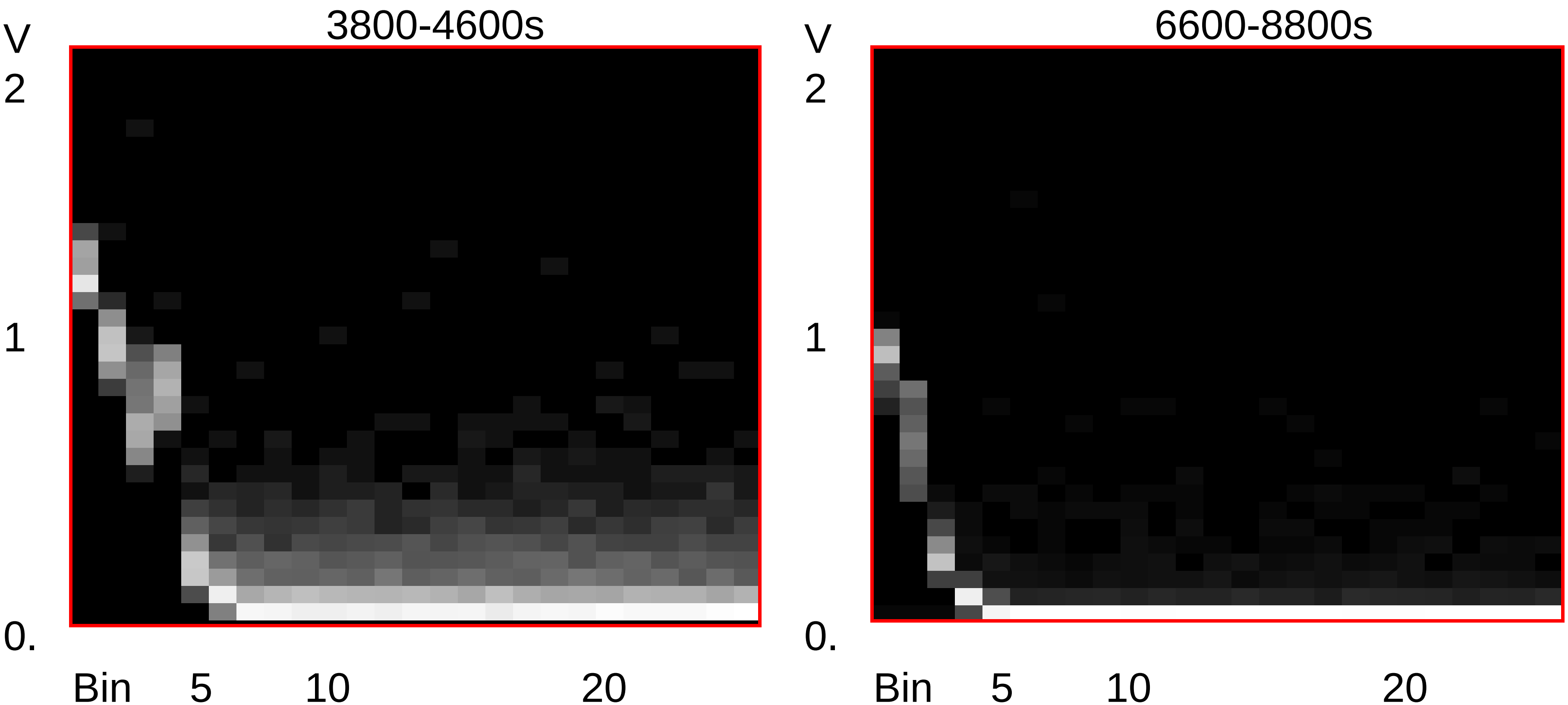
Ralph D. Lorenz[a,b,*], John C. Zarnecki[b], Martin C. Towner[b], Mark R. Leese[b], Andrew J. Ball[b], Brijen Hathi[b], Axel Hagermann[b], Nadeem A.L. Ghafoor[c]

Not obviously voltage noise - likely to be real movement/stress on transducer. But is it echo from cloud, echo from turbulent eddies, or mechanical noise on the sensor ?





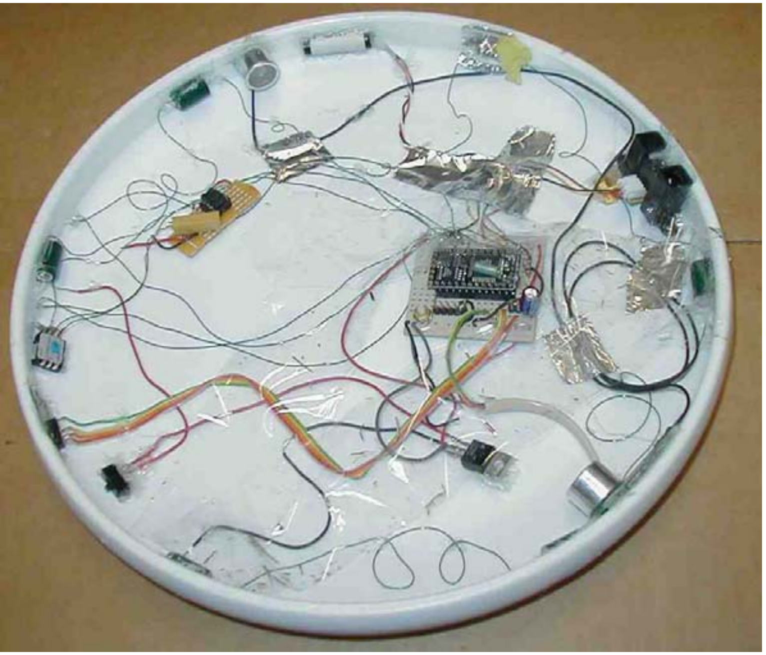
Histogram of signal voltage vs time bin



Signals as likely to occur in distant time bins as they are in nearby bins.
Appears to reject the hypothesis that most signals are echoes.

A real environmental signal (but peak in acoustic data cut off by noise before peak in Tilt signatures reached) but not echoes - structural creaking excited by turbulence?

Use microphone as indicator of flow separation ?

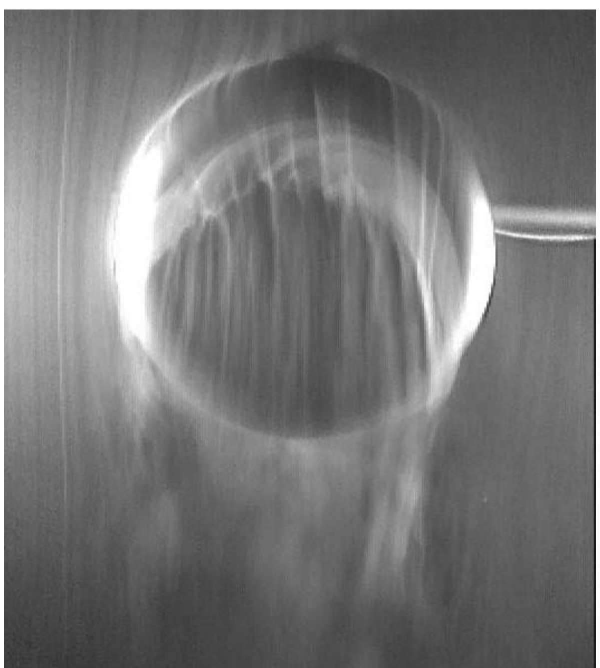


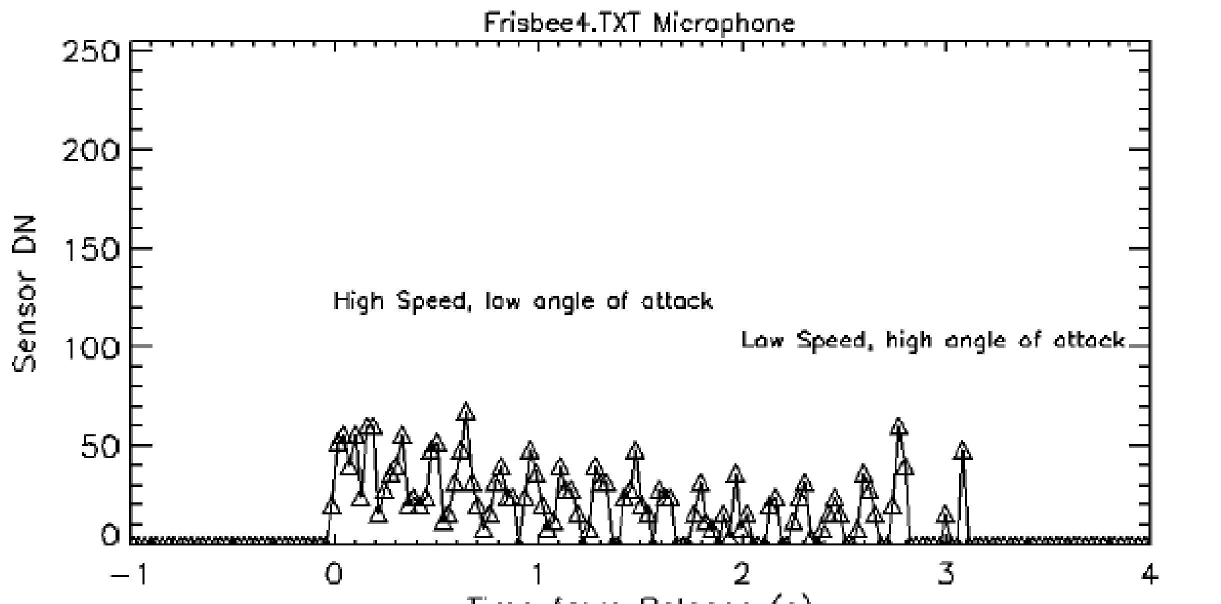
INSTITUTE OF PHYSICS PUBLISHING MEASUREMENT SCIENCE AND TECHNOLOGY

Meas. Sci. Technol. 16 (2005) 738–748 doi:10.1088/0957-0233/16/3/017

Flight and attitude dynamics measurements of an instrumented Frisbee

Ralph D Lorenz

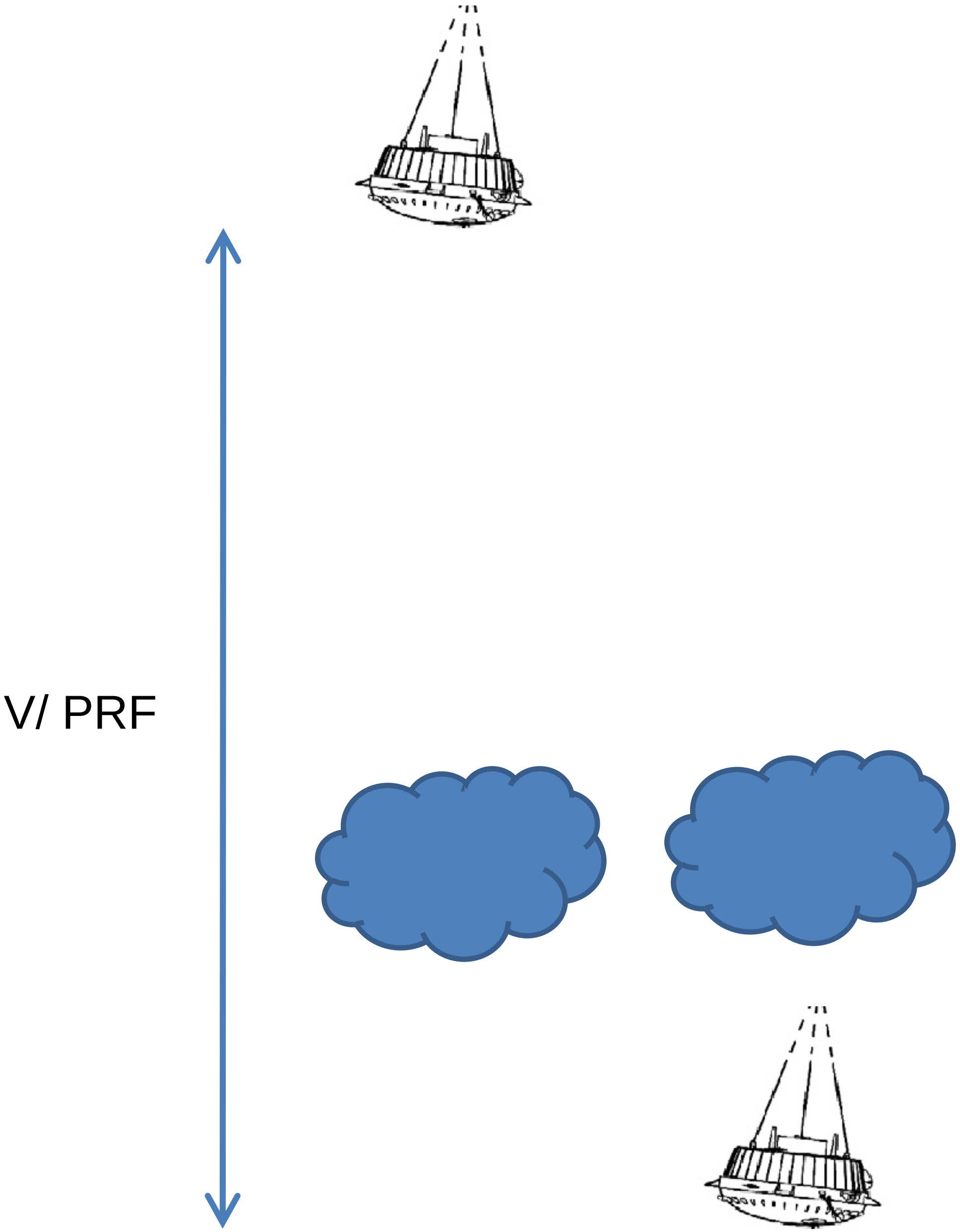




Acoustical Measurements are challenging from a rapidly moving vehicle.

- Perception of a parachute-borne probe as a gently descending object is wrong. Fast and noisy
- Balloon-drop or similar testing should have been carried out
- ACP pump was identified as a potential noise source during development - why was it a problem for SSP?   (and why is signature not obvious on HASI - structurally conducted rather than acoustically radiated ?)
- Science impact of HASI ACU has been modest, but outreach value not insignificant

- Zero offset - important in measuring low surface winds



Being sure about a few detections is better than having many possibles.

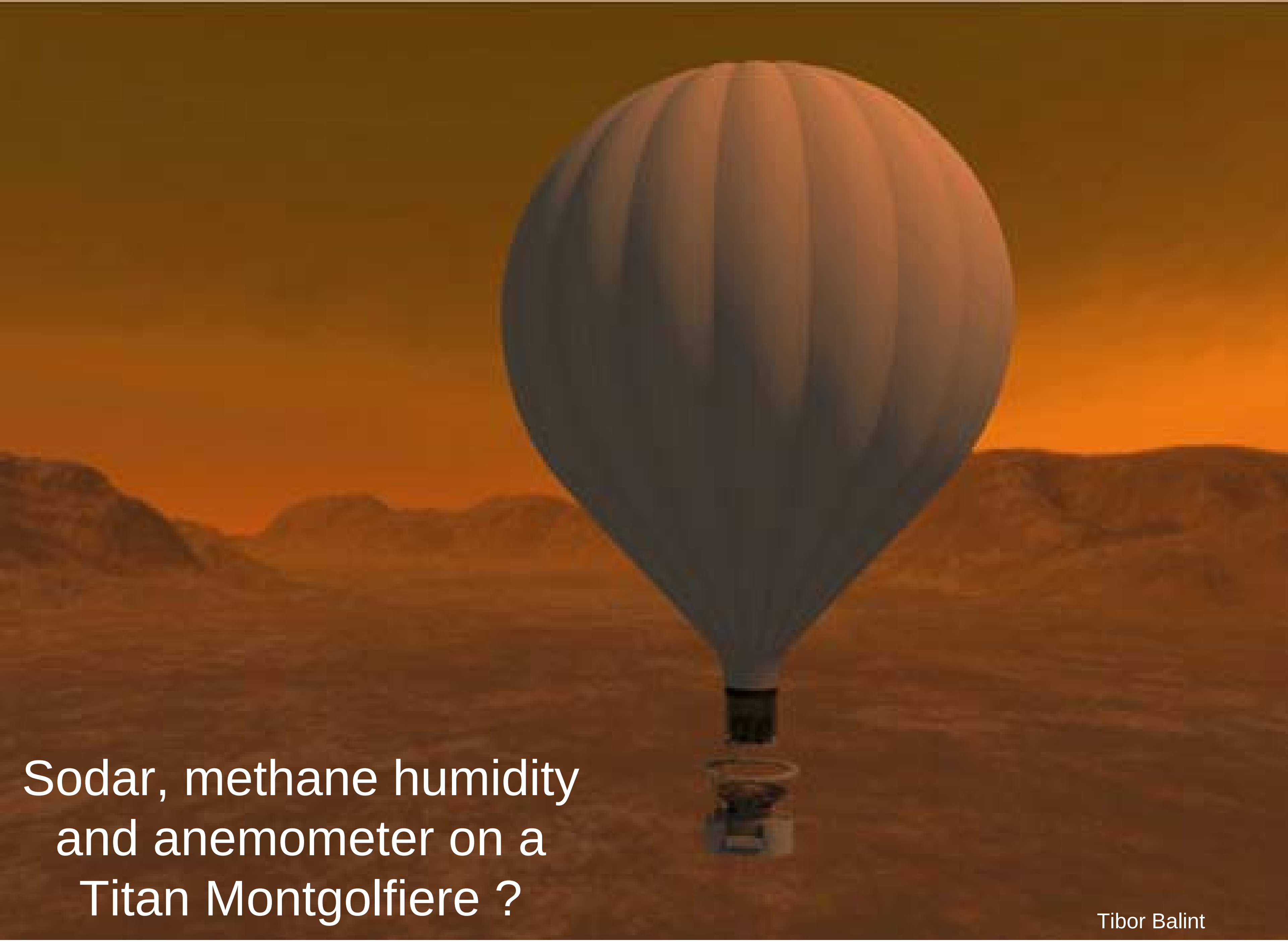
Want multiple echoes (>3) of same reflecting structure (i.e. high PRF; though NB range ambiguity is a challenge for 'relativistic' regime (V~c)

Adapt sampling strategy to descent rate - burst mode

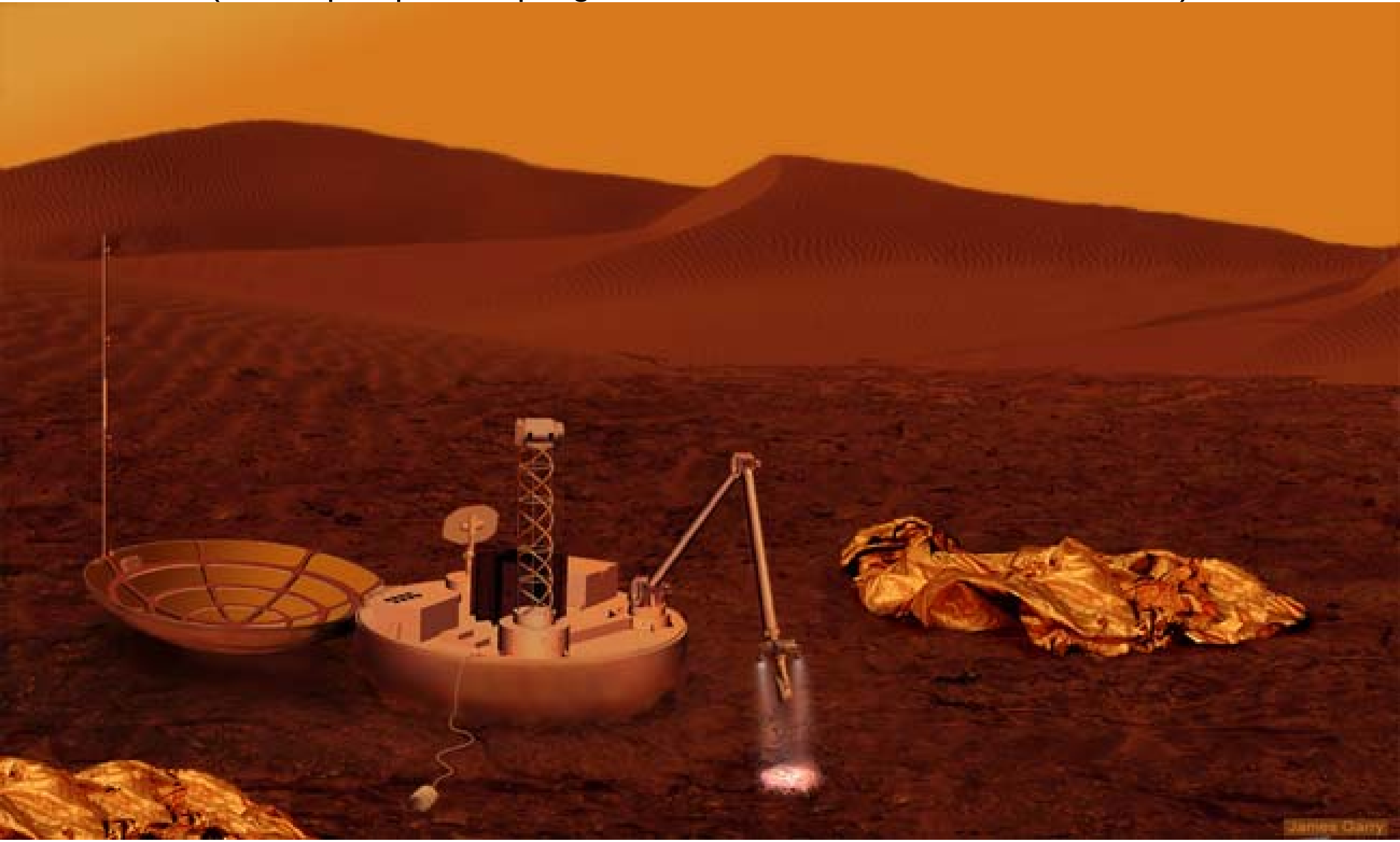
Acoustic measurements too 'novel', too nonspecific to merit dedicated acoustic instrument ?

Need to piggyback microphone on 'package' instruments like SSP or atmospheric structure, and/or invoke its outreach appeal.

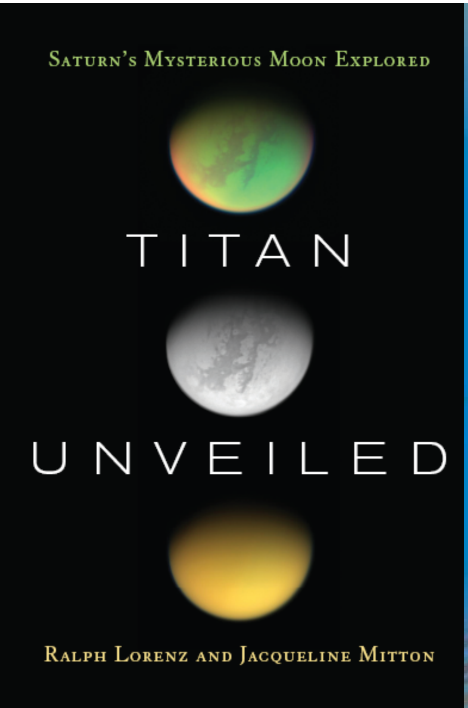
(NB speed of sound a useful measure of methane humidity on Titan; also diagnostic of ortho:para hydrogen ratio in giant planet atmospheres. Acoustic anemometers are also a promising technique)


Sodar, methane humidity
and anemometer on a
Titan Montgolfiere ?
Tibor Balint

Acoustic instrumentation on a Titan lander - methane humidity, anemometry, detection of saltation or waves (dunes v liquid) Infrasound from bolides, cracks from tidal stresses. Booming dunes?   Also engineering/outreach of mechanism operation (doors, pumps, sampling arm, Titan Bumblebee UAV takeooff..)



Fin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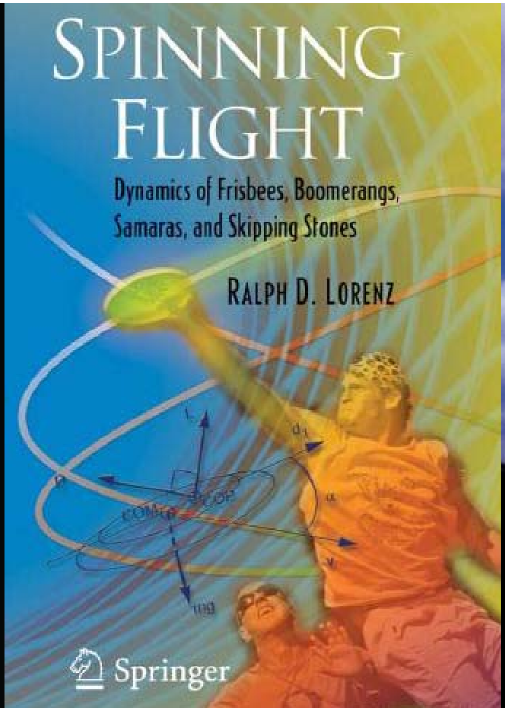
TITAN
UNVEILED
Ralph Lorenz and Jacqueline Mitton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Ralph D. Lorenz
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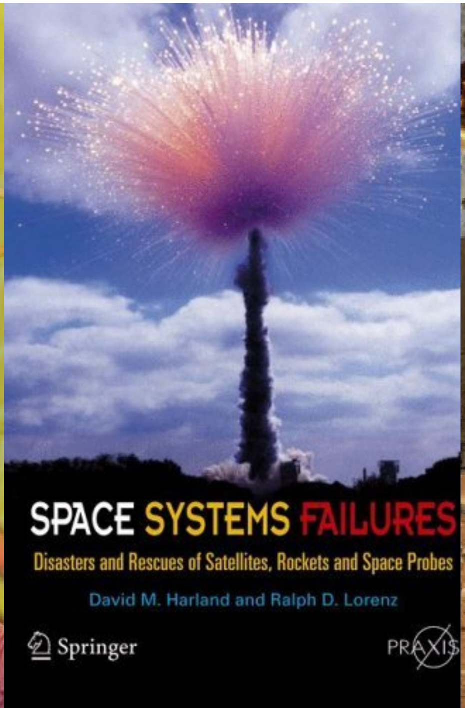
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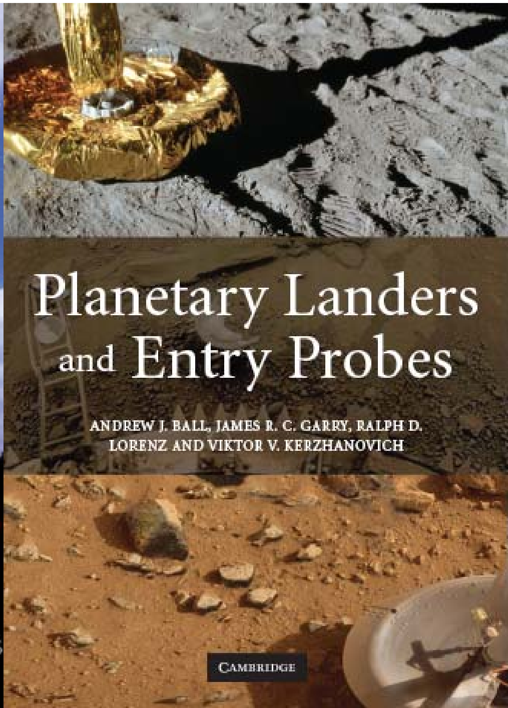
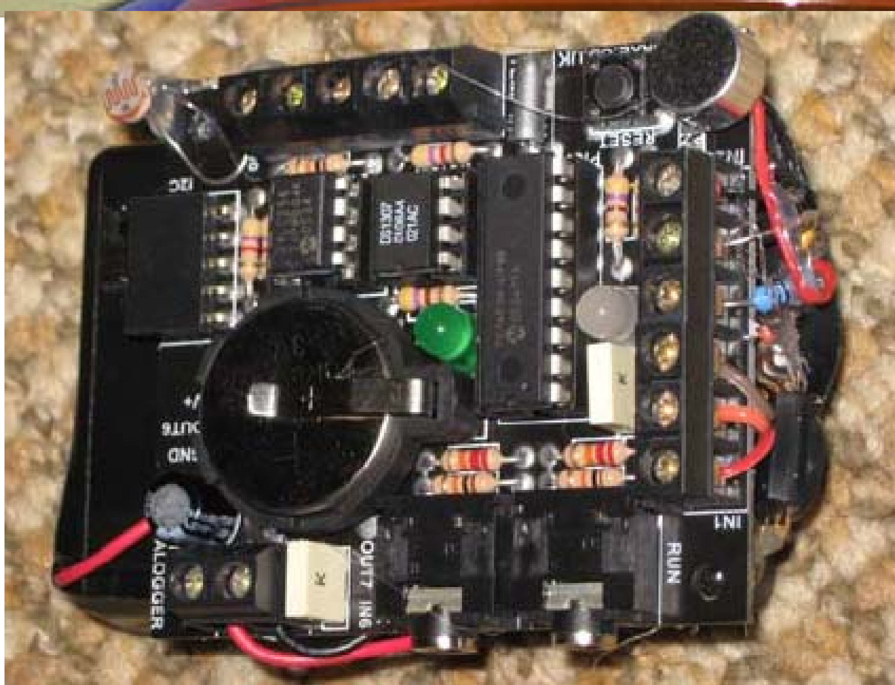

Planetary Landers and Entry Probes
ANDREW J. BALL, JAMES R. C. GARRY, RALPH D. LORENZ AND VIKTOR V. KERZHANOVICH
CAMBRIDGE

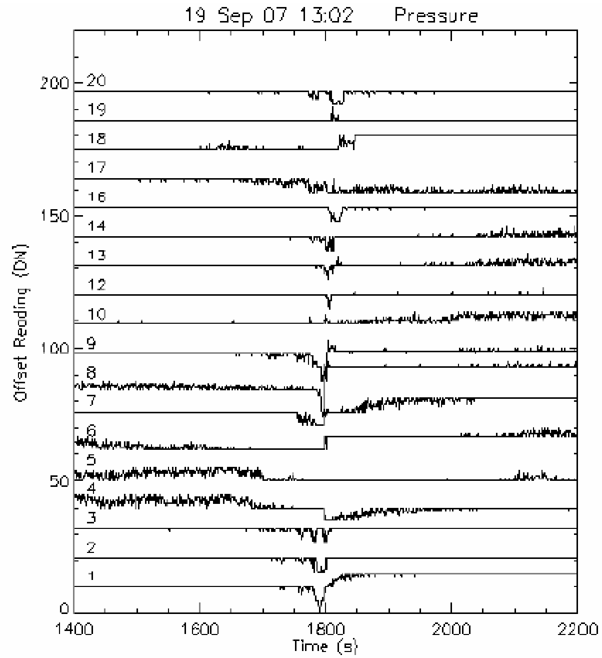


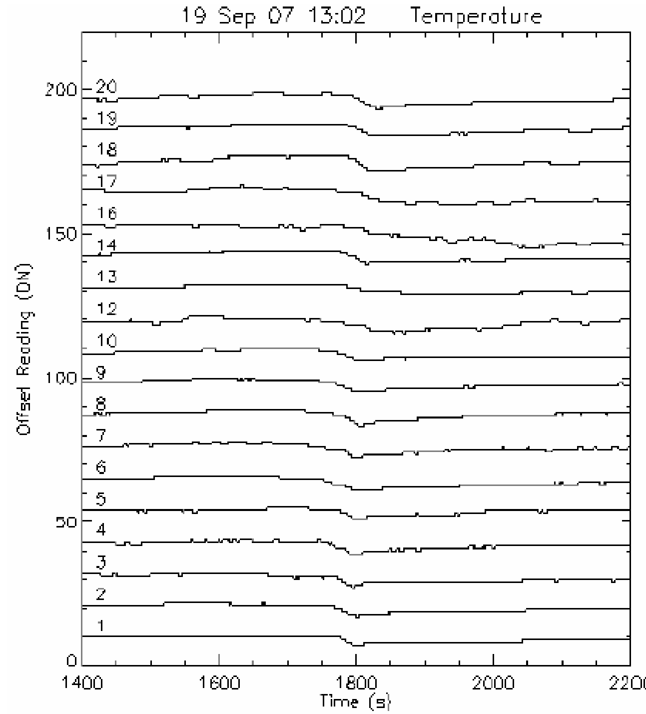
Tucson, September 2007

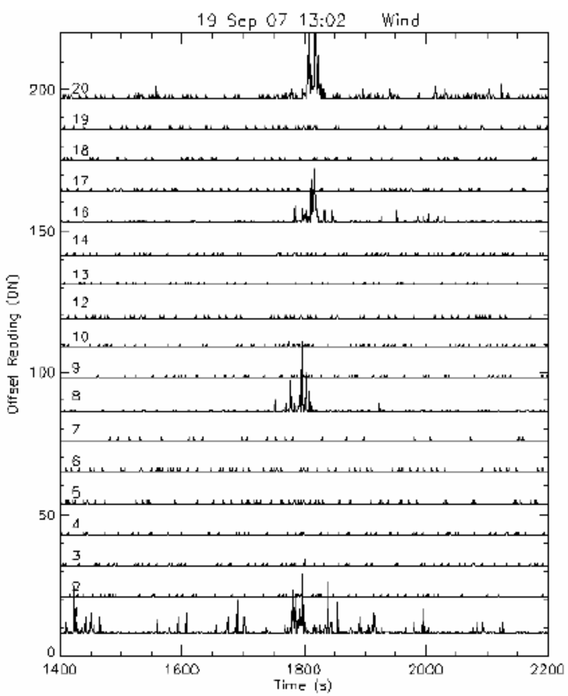
Linear array of 20 stations deployed E-W (PICAXE 18X datalogger)

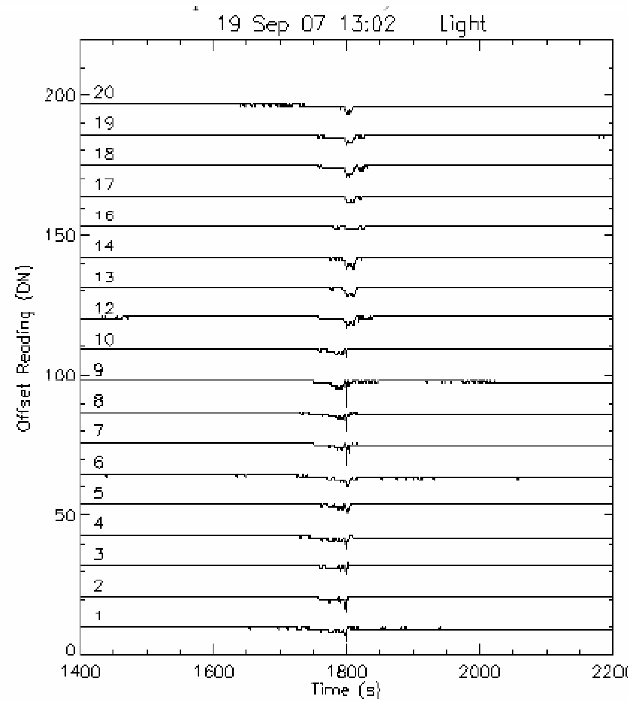
Set to record 1 hour of 1/s 1-byte data of pressure, temperature, light, microphone (numerically differenced-summed)

Encountered large dust devil after ~30 minutes


19 Sep 07 13:02 Pressure
Offset Reading (DN)
Time (s)


19 Sep 07 13:02 Temperature
Offset Reading (DN)
Time (s)


19 Sep 07 13:02 Wind
Offset Reading (DN)
Time (s)


19 Sep 07 13:02 Light
Offset Reading (DN)
Time (s)